8. GREEN FINANCING STRATEGIES AND POLICY INTERVENTIONS: DRIVING SUSTAINABLE DEVELOPMENT IN EUROPE'S LARGEST ECONOMIES

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Abstract

The Target of the world is that economic growth must be sustainable, ensuring optimized production and reduced emissions. This study examines the impact of green financing strategies, including MPT (Industrial green innovation), IMPT (Eco-tech imports), GFN (Green investment), MTW (Water and wastewater-related green technologies), and MTE (Energy-related green technologies). It also estimated the impact of policy interventions, such as EPY (Environmental policy) and ETX (Environmental taxes), on production-based emissions (PBE), industrial value addition (IVA), and sustainable development goals (SDG). The analysis focuses on the data of 9 largest economies of Europe, which contributed 83% of total EU GDP from 2000 to 2022. The CIPS test is used to evaluate unit roots, and 2nd generation tests are applied to evaluate cross-sectional dependence. Furthermore, to estimate the parameters, we used the Pooled Augmented Mean Group (AMGE) estimator and The Common Correlated Effects Mean Group (CCEMG) estimator. The Bootstrap Granger Causality test is also applied. The results affirm that all the green financing strategies and policy interventions that were considered mitigated PBE and increased the IVA and SDG in Europe. Notably, the impact of green investment mitigation is prominent. Therefore, European policymakers should expand investment in green technologies and sustainable practices across all sectors. For this purpose, government intervention in the form of environmental policies and environmental taxes is also recommended. This will ensure continued mitigation of pollution and progress toward Sustainable Development Goals in Europe.

Keywords: Green financing strategies; Policy interventions; Production-based emissions; Industrial value addition; Sustainable Development Goals; Europe.

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1. Introduction

The 2015 UN initiated Sustainable Development Goals (SDGs), which are a global roadmap for a better and more viable future. The SDGs provide a framework to achieve environmentally friendly growth (Wang *et al.,* 2023). Europe is currently going through a development phase that focuses on sustainability. Moreover, Europe is endeavoring to advance its industrial base and strong policy frameworks to address environmental challenges (Khurshid *et al.,* 2024). In this regard, the European Union has committed to aspiring targets, which include reducing greenhouse gas emissions without hampering growth and achieving climate neutrality by the year 2050 (Cifuentes-Faura, 2022). These commitments highlight the critical role of Europe in the global sustainability agenda and for the long-term well-being of its citizens.

Europe is also focusing on its extensive legislative policy initiatives and substantial investments in green technologies for sustainable development (Mengxuan *et al.,* 2024). The European Green Deal is a significant project in this endeavor. It seeks to get a resource-efficient and competitive economy. It encompasses a broad spectrum of activities that range from improving energy use and advocating for renewable energy to applying circular economy ideas (Munta, 2020). Moreover, Europe's endeavors extend beyond internal actions, and it actively participates in international climate plans. They endorse global initiatives and collaborations that target environmental issues. Europe's role in pushing the global sustainability agenda is vital as it sets high aims and leads by example. Their target is to achieve economic growth and environmental care simultaneously.

Ojekemi *et al.* (2022) assert that innovation and investment in green technologies are key drivers and important measures of progress toward the SDGs. Furthermore, governments are implementing changes in their industrial sectors that are in line with the SDGs, with a particular focus on enhancing effective technologies (Xie *et al.,* 2022). Few European countries have made some progress in achieving these notable goals by investing in green technologies (Chen *et al.,* 2023). However, many countries worldwide have not adequately implemented steps to address the climate change menace (Cheng *et al.,* 2021). The adoption of ecologically sustainable technologies in the industry, such as grid transformation and switching towards clean energy sources, has substantial and wide-ranging environmental impacts (Ulucak & Khan, 2020).

Europe is more concerned about clean growth and investing in industrial innovation and technologies (Ma *et al.,* 2023). To achieve all SDGs, the countries can't ignore the production process but can switch towards greener practices. For this purpose, Europe has implemented the notion of sustainable consumption and production along with the Sustainable Industrial Policy Action Plan (Lélé, 1991). This includes innovations and investment in renewable energy, energy efficiency, and cleaner production processes. Furthermore, policy measures such as carbon pricing, emission trading schemes, and stringent environmental regulations incentivize industries to adopt greener practices are also included in the plan. These technological and policy frameworks not only mitigate emissions but also promote sustainable industrial growth in Europe (Khurshid *et al.,* 2022).

To achieve environmental growth having in line with SDGs, both the government and the citizen's mutual struggle is required (Liu *et al.,* 2024). The concept of green innovation means economic growth, which ensures environmental safety. However, the adverse effects of climate change significantly impact the industrial organization and other areas. Additionally, the profit-driven objective of the firms reduces their inclination to pursue innovation proactively. Consequently, there is a pressing requirement for intervention from the external side, such as environmental regulation, to be imposed or directed to address this issue (Wang *et al.,* 2022). In Europe, for environmental preservation, carbon tax is a famous policy tool (Wolde-Rufael & Mulat-

Weldemeskel, 2023; Khurshid *et al.,* 2022). So, green mitigation technologies and effective policy interventions are crucial in shaping the global sustainability agenda by reducing emissions, increasing industrial value addition, and advancing sustainable development (Anzolin & Lebdioui, 2021).

Based on the above debate, the main goal of this work is to examine the impact of green financing strategies, specifically MPT- Industrial green innovation, IMPT - Eco. Tech. Imports, GFN - Green investment, MTW - Water and wastewater-related green technologies, and MTE - Energy-related green technologies, as well as policy intervention, including EPY- Environmental policy and ETX- Environmental taxes, on production-based emissions (PBE), industrial value addition (IVA), and sustainable development goals (SDG) in European countries. The specific research questions, on the basis of which empirical models are formulated are as follows:

- *How do green strategies and policy factors influence production-based emissions, which can drive the biggest European economies towards a sustainable path?*
- *What are the cumulative impacts of major determinants such as green innovation and green tech imports, trade globalization, and R&D on industrial value addition, providing insights on how to improve industrial sustainability and resilience?*
- *How do green strategies affect Sustainable Development in Europe?*
- *How can green mitigation technologies and policy interventions influence the global sustainability agenda by reducing emissions, increasing value addition, and making progress toward Sustainable Development?*

The current study is intended to explore how green financing strategies and policy interventions influence PBE, IVA, and SDG in selected nine largest economies of Europe, which contribute 83% of the total EU GDP.[6] The main focus is to explore the role of policy interventions and green strategies in sustainable development in Europe through industrial optimization. As the selected economies are the main contributors to the EU and have the same objectives and constraints, they must be explored to achieve the target of sustainable development. This combination has previously been ignored in empirical studies. The outcomes of the current work highlight the targeted green financing and policy interventions that are intended to achieve clean and green growth in Europe.

This endeavor offers many other novel contributions to the area of sustainable development. It distinctively examines the influence of various aspects of green technological and policy factors on PBE. In this, it considers related variables such as green finances (GFN), eco-tech imports (IMPT), industrial green innovation (MTP), environmental policy (EPY), industrial energy consumption (ECI), and trade globalization (TGL). This is intended to capture the multifaceted influences driving emissions reduction. This is aimed at a better understanding of how various aspects influence the steering of European economies towards a sustainable path. Further, this work advances knowledge of industrial sustainability by investigating the cumulative impacts of green innovation, green tech imports, trade globalization, and R&D on IVA. The inclusion of PBE and environmental taxes (ETX) further enriches the current work. This is intended to explore how environmental and economic policies can be combined to enhance industrial resilience and sustainability. Moreover, it explores the broader implications of green solutions for sustainable development. This is done by focusing on specific green mitigation technologies like (MPRE, MTW, and MTE) and their contributions to achieving the Sustainable Development Goals (SDG). This highlights how targeted investments in green technologies and effective policy frameworks

[6] The $16 Trillion European Union Economy. https://www.visualcapitalist.com/16-trillion-european-union-economy/#google_vignette

can accelerate progress towards global sustainability objectives. Also, the empirical models employed are linking production-based emission (PBE), industrial value added (IVA), and SDG outcomes. This offers a rigorous methodological framework for analyzing complex interrelationships. By estimating these models, this work delineates pathways through which green strategies and policy interventions influence economic and environmental outcomes. It will also provide actionable insights for enhancing industrial sustainability. Lastly, the findings have broader implications for the global sustainability agenda. The Europe's leadership in green policies and technologies serves as a benchmark for other regions. It demonstrates how integrated strategies can achieve industrial optimization. In addition, the study employs rigorous analytical approaches with robustness checks to strengthen its outcomes.

This endeavor is methodically structured to address its research objectives across multiple sections. Section 2 provides a critical literature review. Section 3 explains the details of the data and the research methodology employed. The subsequent section has the results and discussion. The concluding section summarizes the study, highlights policy implications, and acknowledges its limitations.

2. Literature review

The literature on sustainable development with respect to industrial optimization and emission reduction is vast and multi-faceted. It contains various aspects of policy interventions and green strategies. This section reviews the key studies in these areas. It highlights the role of policy measures and green technologies in driving industrial sustainability.

2.1 Role of green financing strategies on industrial sustainable optimization

The first part of this section focuses on green financing strategies or solutions for industrial pollution. There are many green strategies, like technological innovation and eco-friendly practices, that can influence industrial sustainability. In the past, Rennings (2000) highlighted the significance of eco-innovation in reducing environmental impacts and improving resource efficiency. Additionally, De Marchi (2012) showed that integrating green strategies into business operations can lead to improved environmental and economic outcomes. They argued that firms investing in green R&D are more likely to develop innovative solutions that drive sustainability. Similarly, Khurshid and Deng (2021) found that R&D expenditures are very important for green growth in industrialized countries. These findings illustrate the critical role of green strategies in fostering sustainable industrial development.

Recently, Ma *et al.* (2023) investigated the influence of innovation and technologies in the industrial sector on production-based emissions (PBE). The study was conducted in European countries from 1994 to 2021. The research showed that innovative technologies and renewable energy played critical roles in reducing PBE. They also highlighted the significance of industrial innovation for sustainable development. Similarly, Li *et al.* (2023a) inspected the impact of mitigation technologies on CO_2 in OECD regions from 2000 to 2018. The results confirmed that the mitigation technologies neutralized PBE in the OECD region. Similarly, Khurshid *et al.* (2023a) tried to highlight the direction to achieve the SDGs through green innovations and renewables in OECD economies from 1990 to 2020. The findings affirmed that the green innovation reduced emissions. They also found that carbon tax decreased CO_2 emissions in the studied area. Furthermore, Duan *et al.* (2024) examined the viewpoints of professional technologists within industrial structures. Results revealed that the mitigation technologies contributed to production sustainability.

2.2 Role of policy interventions on industrial sustainable optimization

A number of studies have examined the impact of policy interventions on industrial sustainability. Like, Porter and Linde (1995) argued that proper environmental regulations can stimulate innovation which leads to both economic and environmental benefits. Similarly, Berman and Bui (2001) initiated that environmental regulations in the U.S. petroleum industry led to substantial reductions in emissions without hindering productivity. Furthermore, Ambec *et al.* (2013) explored the policy factors that are related to sustainable growth. They provided empirical evidence supporting the Porter Hypothesis. They showed that stringent environmental policies enhanced industrial competitiveness by encouraging eco-innovation. These past studies collectively highlighted the importance of regulatory frameworks in promoting industrial sustainability through innovation and efficiency improvements.

Recently, Khurshid *et al.* (2023b) inspected the role of environmental regulations on environmental sustainability via clean production plans. They showed that environmental policies helped reduce emissions in Europe. They also regarded carbon pricing as a main driver for achieving green growth. Similarly, Wang *et al.* (2023) conducted study for China from 2009 to 2020. They examined how environmental regulations impacted green innovation. They found that environmental regulations enhanced green technology innovation. Similarly, Khurshid *et al.* (2024) stated that environmental regulation motivated the producers to switch towards more sustainable technologies to achieve SDGs. They inspected the influence of environmental regulations on green technologies and innovation in Europe from 1994 to 2020. They found that environmental policies and government intervention are necessary to drive innovation and sustainable production. Furthermore, Saleem *et al.* (2024) examined the influence of government policy intervention on economic growth and environmental degradation in the MENA region. The study used data from 2002 to 2020. Results indicated mitigating the impact of government intervention and effectiveness on carbon emissions.

2.3 Research gap

There is plenty of research on the role of policy interventions and green financing strategies in industrial sustainability. However, there is a limited understanding of the combined effects of these factors on production-based emissions, industrial value addition, and progress toward SDG. Most studies have focused on isolated aspects of policy or technology without considering their interactive impacts. To achieve environmental growth aligned with SDG, both the government and the public involvement are required (Liu *et al.,* 2024). Green innovation, which includes economic growth, environmental protection, and resource conservation, is crucial but hampered by the profit-driven nature of enterprises necessitating external interventions like environmental regulation (Wang *et al.,* 2022). The current study addresses this gap by integrating both policy interventions and green technological advancements in a comprehensive empirical framework. By doing so, it provides a better analysis of how these factors jointly influence industrial optimization and sustainability in Europe. Moreover, the combination of the largest economies of Europe, contributing 83% of the total EU GDP, is a contribution to the literature. This will provide targeted ideas for policymakers and industry stakeholders to attain sustainable production.

3. Data with empirical models and empirical strategy

3.1 Data

The time for the study is from 2000 to 2022. The period is limited based on the availability of consistent data. The study selected 9 largest economies (AUS, BEL, FRA, DEU, ITA, NLD, POL, ESP, and SWE) which contribute 83% of the total EU GDP.[7] Table 1 provides details.

Table 1: Variables details with descriptive statistics

Variable	Description	Mean	Std. Dev.	Min	Max	Data
SDG	Sustainable Development goals	78.20	2.69	71.42	83.36	SDG Report
GFN	Green Investment	10.21	0.86	8.45	11.67	OECD Sources
IMPT	Import of green technology	22.44	0.77	20.65	24.38	
RD	Research Expenditures	8.71	0.92	7.18	10.84	
ETX	Ecological Taxes	9.95	0.85	8.10	11.31	
EPY	Ecological Policies	2.20	1.10	0.00	4.560	
URB	Urbanization	17.11	0.85	15.89	18.24	
PBE	production-based emission	335.4	263.3	72.24	1018.	
TGL	Trade globalization	80.29	7.54	61.07	90.06	
IVA	Industrial output	24.22	1.43	21.04	26.78	
MTP	Green production tech.	14.89	4.17	6.65	30.26	
ECI	Fossil fuel consumption (Industries)	31.45	20.94	6.93	85.91	
MTW	Water and waste water green tech.	4.97	2.46	1.25	14.38	
MTE	Green energy tech.	21.90	6.16	6.95	36.97	
EGL	Economic globalization	80.75	8.26	52.40	92.85	
MPRE	*(MTP*RNG)* Interaction of green production and processing tech. and green energy.					

Note: It's an author's calculations and compilation

3.2 Theoretical and empirical modeling

The theoretical modeling for this study integrates several economic theories to understand how green technological advancements and policy interventions impact production-based emissions, industrial value addition, and sustainable development. The models are structured around the principles of environmental economics, innovation economics, and trade theory. The first PBE empirical model is based on the principles of environmental economics, particularly the theories of externalities and environmental regulation. It examines how green strategies and policy factors

[7] The $16 Trillion European Union Economy. https://www.visualcapitalist.com/16-trillion-european-union-economy/#google_vignette

influence PBE, which are considered negative externalities of industrial activities (Jakob *et al.,* 2014).

The dependent variable is PBE, with industrial green innovation (MTP) as the independent variable. This variable is technological advancements aimed at reducing environmental impact, which aligns with the Porter Hypothesis. It proposes that stringent environmental regulations improve innovation (khurshid *et al.,* 2023c; Khan & Khurshid, 2024). Eco-tech imports (IMPT) reflect the diffusion of green technologies across borders, as informed by international trade theory, which posits that trade allows countries to access superior technologies and reduce emissions (Khan *et al.,* 2022). Green finances (GFN) refer to investments in green technologies. The theory of green finance supports this. That theory encourages funding environmentally beneficial projects. Furthermore, environmental policy (EPY) reflects regulatory frameworks aimed at reducing emissions. That is consistent with the Pigovian tax principle. This principle advocates for taxing negative externalities (Khurshid *et al.,* 2022). The variable of energy consumption in industries (ECI) represents the scale of industrial activity. Moreover, trade globalization (TGL) is showing the influences of emissions through economic integration and access to cleaner technologies.

Based on the above-discussed variables, the first empirical model is specified as follows:

$$PBE_{it} = \sigma_0 + \gamma_1 MTP_{it} + \gamma_2 IMPT_{it} + \gamma_3 GFN_{it} + \gamma_4 EPY_{it} + \\ + \gamma_5 ECI_{it} + \gamma_6 TGI_{it} + u_{it} + \epsilon_{it} \quad (1)$$

for t = 1……..,*T* and *i* = 1………, *N*

The second industrial value addition (IVA) empirical model draws from innovation economics and the theory of endogenous growth. These theories emphasize the role of R&D and innovation in driving growth. It assesses the determinants of IVA. That includes industrial green innovation (MTP). This drives productivity and efficiency, leading to increased value addition (Zhang *et al.,* 2022). Moreover, eco-tech imports (IMPT) enhance industrial sustainable capabilities through technology transfer (Liu *et al.,* 2023). The research and development (RD) expenditures support endogenous growth theory, which posits that R&D investments foster innovation and economic growth (Aghion *et al.,* 1998). Other independent variables include trade globalization (TGL), which facilitates market expansion and competitive advantages. The Green Finances (GFN) represent investments that promote sustainable industrial practices (Ma *et al.,* 2023). At last, environmental taxes (ETX) are included as policy measures that align with the double dividend hypothesis. That suggests that environmental taxes can yield economic and environmental benefits (Khurshid *et al.,* 2023b).

Based on the above-discussed variables, the second empirical model is specified as below:

$$IVA_{it} = \sigma_0 + \gamma_1 MTP_{it} + \gamma_2 IMPT_{it} + \gamma_3 RD_{it} + \gamma_4 TGL_{it} + \gamma_5 GFN_{it} + \\ + \gamma_6 ETX_{it} + u_{it} + \epsilon_{it} \quad (2)$$

The third and last empirical model of sustainable development goals (SDG) integrates elements from sustainable development theory and innovation economics. It examines how various determinants contribute to achieving the SDG. The independent variables include Water and wastewater-related green technologies (MTW). It is supposed to improve environmental quality and resource efficiency and energy generation and treatment-related green technologies (MTE) that are supposed to advance in sustainable energy that reduce emissions and promote clean energy (Mao *et al.,* 2022). The green finances (GFN), economic globalization (EGL), urbanization (URB), and industrial value addition (IVA) are also included in the empirical model as independent variables (Khurshid *et al.,* 2023b; Ma *et al.,* 2023).

Based on the discussion, the third empirical model is specified as below:

$$SDG_{it} = \sigma_0 + \gamma_1 MPRE_{it} + \gamma_2 MTW_{it} + \gamma_3 MTE_{it} + \gamma_4 GFN_{it} + \quad + \gamma_5 EGL_{it} + \\ + \gamma_6 URB_{it} + \gamma_7 IVA_{it} + u_{it} + \epsilon_{it} \quad (3)$$

In Equations 1, 2, and 3, PBE_{it}, IVA_{it} and SDG_{it} are the dependent variables for individual *i* at *t* time. The γs show the parameter values and u_{it} embodies the time-invariant inarticulate influences in three empirical models, which can affect dependent variables, and ϵ_{it} are the disturbance terms.

3.3 Empirical strategy

First, we calculate the descriptive statistics to gain a quantitative understanding of the individual variables. Following that, a thorough examination of cross-section dependence (CD) is conducted. It is crucial because of its potential to influence usual shocks (Wang *et al.,* 2022). Not accounting for CD in an investigation can result in inaccurate results, as demonstrated by Li *et al.* (2023a). For this purpose, the CD test proposed by Baltagi and Pesaran (2007) is employed. After confirming the presence of the CD, it is concluded that 1st generation stationary analyses are not appropriate. Therefore, the study utilizes 2nd generation stationary test of cross-sectional augmented IPS (CIPS) developed by Pesaran (2007) and applied by many like (Rauf *et al.,* 2018).

In our instance, T>N and the presence of cross-sectional data prevent us from using standard approaches. So, this study uses the Augmented Mean Group (AMG) estimator and the Common Correlated Effects Mean Group estimator (CCE-MG) to eradicate estimate bias and ensure the robustness of the findings (Chudik & Pesaran 2015). The Common Correlated Effects Mean Group (CCEMG) estimator, which was first developed by Pesaran in 2006, is a more advanced econometric method used to deal with cross-sectional dependence and heterogeneity in panel data models. The estimator recognizes that associations between variables may vary across cross-sectional units and permits heterogeneous slope coefficients across those units (Adeneye *et al.,* 2021). The dataset should have a bigger time dimension (T) than a cross-sectional dimension (N). However, the estimator can still be used in a variety of panel data situations. The fundamental framework for a cross-section unit *i* is defined as follows:

$$y_{it} = \sigma_i + \beta_i' x_{it} + \gamma_i' \bar{x}_t + \epsilon_{it} \quad (4)$$

Where y represents the dependent parameter, x is a set of descriptive factors, x are the standard values of the descriptive parameters across the cross-sectional units, α denotes the intercept specific to each unit, β represents the slope parameters related to each unit, and ϵ represents the term for error. The following formulas are used to determine the cross-sectional average of the independent and dependent variables:

$$\bar{y_t} = \frac{1}{N}\sum_{i=1}^{N} y_{it}\,, \bar{x_t} = \frac{1}{N}\sum_{i=1}^{N} x_{it},$$

The Augmented Mean Group (AMG) estimator, proposed by Eberhardt and Bond (2009) and expanded upon by Eberhardt and Teal (2010), is a robust econometric tool for addressing heterogeneity and cross-sectional dependency in panel data analysis. AMGE supports diverse slope factors across cross-sectional dimensions. This adaptability is critical for understanding the varied interactions between variables that can differ between units. The estimator accommodates cross-sectional variability by incorporating fundamental dynamic processes into the model (Xia *et al.,* 2022). The augmented model estimates independently for every cross-sectional unit. This stage yields unit-specific coefficient estimations. The fundamental framework for a cross-section unit *i* is defined as follows:

$$y_{it} = \sigma_i + \beta_i' x_{it} + \chi_i' f_t + \epsilon_{it} \quad (5)$$

Where y_{it} represents the dependent parameter, χ_i' denotes a set of explanatory variables, σ_i reflects the intercept, β signifies the coefficients of the slope, f represents the prevalent variables, and ϵ symbolizes the error term.

The causality between variables is assessed using the Bootstrap Granger Causality method. By generating numerous bootstrap samples, this technique overcomes the limitations of standard Granger causality tests. It also helps to more dependably evaluate causality even in the presence of non-normality and heteroscedasticity (Khurshid *et al.,* 2024). This work establishes a causal link between GFN-IVA and INV-SDG using the panel data causality approach invented by Kónya (2006). The bivariate finite order vector autoregressive model serves as the foundation for this panel causality technique.

4. Results and discussion

4.1Results of preliminary testing

The descriptive statistics values are provided in Table 1, along with the descriptions of the variables. The data analysis shows that the variable PBE has the greatest average value among the other variables that indicate different characteristics of PBE. Conversely, the variable EPY represents the lowest average value. Additionally, it is important to mention that the PBE exhibits the highest standard deviation value. This suggests that both the PBE display a significant amount of variation in their values compared to the average. However, the majority of variables have low standard deviation values, indicating that these variables have little fluctuation and that their mean values properly represent the true values.

Table 2 shows that the CD presence is confirmed, thereby highlighting the interconnectedness among nations. Table 2 also displays the results of the CIPS test. According to the test results, it is evident that the majority of the variables show stationarity when their first differences are taken, while others show stationarity at their original level.

Table 2: Cross-sectional and Unit root results

CD-test		corr	abs (corr)	CIPS							
				Level	10%	5%	1%	1st Diff.	10%	5%	1%
SDG	27.67***	0.962	0.962	-2.816***	-2.12	-2.25	-2.51	-4.594***	-2.1	-2.22	-2.44
GFN	27.82***	0.967	0.967	-2.182*	-2.12	-2.25	-2.51	-4.243***	-2.12	-2.25	-2.51
IMPT	24.33***	0.846	0.846	-2.38**	-2.12	-2.25	-2.51	-4.152***	-2.1	-2.22	-2.44
RD	25.27***	0.878	0.878	-2.579***	-2.12	-2.25	-2.51	-4.573***	-2.1	-2.22	-2.44
ETX	26.98***	0.938	0.938	-2.124*	-2.12	-2.25	-2.51	-4.284***	-2.12	-2.25	-2.51
EPY	-0.6	0.021	0.191	-4.942***	-2.12	-2.25	-2.51	-5.953***	-2.1	-2.22	-2.44
URB	18.07***	0.628	0.699	-1.607	-2.12	-2.25	-2.51	-2.705***	-2.12	-2.25	-2.51
PBE	18.82***	0.654	0.659	-1.651	-2.12	-2.25	-2.51	-4.322***	-2.12	-2.25	-2.51
TGL	9.18***	0.319	0.582	-1.907	-2.12	-2.25	-2.51	-4.552***	-2.1	-2.22	-2.44
IVA	26.85***	0.933	0.933	-1.125	-2.12	-2.25	-2.51	-3.657***	-2.12	-2.25	-2.51
MTP	4.65***	0.162	0.256	-3.055***	-2.12	-2.25	-2.51	-5.493***	-2.1	-2.22	-2.44
ECI	9.68***	0.336	0.587	-2.185*	-2.12	-2.25	-2.51	-4.75***	-2.12	-2.25	-2.51
MTW	14.6***	0.507	0.507	-4.075***	-2.1	-2.22	-2.44	-6.116***	-2.1	-2.22	-2.44
MTE	16.17***	0.562	0.564	-3.188***	-2.12	-2.25	-2.51	-5.974***	-2.1	-2.22	-2.44
EGL	13.8***	0.48	0.588	-2.265***	-2.12	-2.25	-2.51	-4.187***	-2.1	-2.22	-2.44

*Note: ***, **, * p < .01, 0.05, and 0.10*

4.2 Results of CCEMG and AMGE estimators

This study estimated the impact of policy interventions and green financing strategies on industrial optimization and sustainable development through CCEMG and AMGE approaches. The standard deviation of the residuals, which represents the average magnitude of the errors in the model, is denoted by the Root Mean Squared Error (RMSE). Its values are shown in Table 3. A lower value suggests that the model better fits the data. Therefore, we elaborate on the results and compare them with AMGE results since CCEMG has RMSE values in all three cases.

As per CCEMG estimates, in empirical model 1, the outcomes indicate that the green financing strategies (that are: MTP- Industrial green innovation, IMPT- Eco. Tech. Imports and GFN- Green finances) and policy intervention (EPY- Environmental policy) significantly and effectively reduces PBE. The findings demonstrate a significant decrease in the PBE by 1.403, 1.819, 3.163, and 1.031 units as a result of a unit increase in MPT, IMPT, GFN and EPY, respectively, as per CCEMG outcomes. These findings are the same as those of Wang *et al.* (2022), Li *et al.* (2023a), Khurshid *et al.* (2023b), Ma *et al.* (2023) and Duan *et al.* (2024). However, energy consumption in industries (ECI) and trade globalization (TGL) showed a positive impact on PBE at 2.876 and 1.194 units, respectively, as per CCEMG outcomes. The same was found by Li *et al.* (2023b).

For empirical Model 2 with industrial value addition (IVA) as the dependent variable, results reveal that all the independent variables, i.e., MPT, IMPT, GFN, TGL and RD are significantly increasing IVA in 9 European nations, as per CCEMG outcomes. This is supported by many previous studies like Wang (2023) and Ma *et al.* (2023), except for environmental taxes (ETX), which showed a significant and inverse relationship with IVA. It was also elaborated by Kong *et al.* (2023). The findings demonstrate an apparent increase in the IVA by 0.083, 0.131, 1.381, 0.109, and 0.675 units as per CCEMG, as a result of a unit increase in MPT, IMPT, GFN, TGL, and RD, respectively. A 0.138 unit decrease is seen in IVA due to a unit increase in ETX, as per CCEMG estimates.

Furthermore, for empirical model 3, having SDG as a dependent variable, results reveal that the independent variables, including GFN, MTW, and MTE are significantly increasing SDG in 9 European countries, with an increase of 1.419, 0.015 and 0.145 units, respectively. This is supported by many previous studies like Wang (2023), Khurshid *et al.* (2023b) and Sungkawati (2024). However, EGL, URB and IVA showed a negative impact on SDG as per CCEMG estimates, with a decrease of 0.019, 6.291 and -1.040 units, respectively. The same was discussed by Huang *et al.* (2023) and Mwiinde and Munshifwa (2024) in their studies. Furthermore, the interaction of green production and processing technologies and green energy (MPRE) showed a progressive impact on the IVA. It significantly enhances the SDG by 0.369 units.

Moreover, Table 3 shows that the cross-sectional averages of PBE, IVA and SDG (PBE_Avg, IVA_Avg, and SDG_Avg) are also significant. Furthermore, the projected coefficient of c_d_p denotes the estimate's precision and common dynamic process's strength. The common dynamic process (c_d_p) has a low p-value (0.000) in all three models, suggesting that the predicted parameter is highly significant and unlikely to be attributable to randomness. Therefore, it validates the outcomes.

It is also evident that the AMGE estimates are in line with the estimates of the CCEMG. The outcomes of AMGE reveal the same direction of influence and significance for all the variables in all three empirical models. This validates the outcomes obtained by the CCEMG estimator.

4.3 Discussion

The findings of empirical model 1 suggest that focused green advancements and favorable environmental regulations are essential means by which industrial emissions can be reduced. Green strategies stimulate technological innovations and provide financial backing for environmentally favorable initiatives. This ensures less dependence on harmful activities. Moreover, policy interventions like environmental policies establish the essential regulatory framework to enforce and promote these environmentally friendly behaviors. This is a comprehensive approach that considers both market-based and regulatory approaches in attaining SDG in Europe. Moreover, green finances or investments in green technologies have had the maximum impact on reducing harmful industrial emissions. Therefore, investment in green technologies is strongly recommended. However, ECI and TGL showed a positive impact on PBE. This is because of several factors. High energy consumption in industries often relies on fossil fuels. This normally leads to increased emissions despite other green efforts. Additionally, trade globalization can lead to higher production volumes and longer supply chains, which increase emissions due to transportation and less stringent environmental regulations in trading partners.

The findings of empirical model 2 suggest that green strategies, technological imports, financial investments, globalization, and R&D expenditures contribute positively to IVA. This indicates that these factors drive industrial growth and innovation in Europe. The positive impact of PBE on IVA reflects a transitional phase where industries are growing and adding value despite current emission levels. In contrast, the negative impact of ETX on IVA suggests that such taxes are effective in reducing emissions. They can also impose additional costs on industries. This potentially reduces their immediate economic output and value addition. Therefore, there is a need for a balanced approach to policy-making. In which environmental taxes are designed and implemented in a way that mitigates emissions, nevertheless, without hindering industrial growth. This balance is crucial for sustainable development in which economic and environmental goals are aligned.

These results affirm that investments in green technologies and infrastructure in Europe are necessary for sustainable development. European countries can enhance their overall sustainability performance by allocating resources towards renewable energy, efficient water management, and eco-friendly industrial practices. However, the negative impacts of EGL, URB, and IVA on SDG highlight the challenges posed by rapid economic growth and urban expansion. While these factors drive prosperity, they also exert pressure on natural resources, ecosystems, and social cohesion. This is potentially hindering sustainable development efforts. The interaction of green production and processing technologies with green energy (MPRE) presents a promising avenue for long-term sustainable development. European industries can not only enhance growth but also reduce their environmental footprint by applying these policies.

The findings of the current study strongly suggest green solutions for achieving long-term sustainability. This research highlights the effectiveness of green strategies and policy interventions in reducing PBE in Europe. However, challenges such as energy consumption in industries and trade globalization are still present. Moreover, industrial innovation and financial investments contribute to IVA. The ETX exhibits an inverse relationship with IVA. Additionally, the study shows the importance of green technologies and investments in the water and energy sectors in achieving SDGs. Furthermore, the integration of green production and energy technologies (MPRE) shows an enhancing effect on both IVA and SDG attainment.

Table 3: Empirical Outcomes of AMGE and CCEMG

PBE	AMGE	CCEMG	IVA	AMG	CCEMG	SDG	AMG	CCEMG
	Model 1			Model 2			Model 3	
PBE_Avg		0.795***	IVA_Avg		1.257***	SDG_Avg		1.029***
		(0.205)			(0.236)			(0.238)
MTP	-1.722***	-1.403***	MTP	0.102***	0.083**	MPRE	3.082***	0.369***

PBE	AMGE	CCEMG	IVA	AMG	CCEMG	SDG	AMG	CCEMG
	Model 1			Model 2			Model 3	
	(0.472)	(0.366)		(0.003)	(0.002)		(0.266)	(0.335)
IMPT	-2.218**	-1.819***	IMPT	0.098**	0.131*	MTW	0.014*	0.015*
	(1.085)	(0.739)		(0.042)	(0.086)		(0.006)	(0.0069)
GFN	-2.834*	-3.163*	RD	0.571**	0.675**	MTE	0.123*	0.145*
	(1.347)	(1.657)		(0.030)	(0.240)		(0.015)	(0.018)
EPY	-1.417***	-1.031**	TGL	0.211**	0.109	GFN	0.494**	1.419**
	(0.419)	(0.520)		(0.005)	(0.006)		(0.203)	(0.182)
ECI	3.007***	2.876***	GFN	2.311***	1.381***	EGL	-0.216**	-0.019*
	(0.572)	(0.809)		(1.058)	(0.279)		(0.029)	(0.009)
TGL	1.258***	1.194***	ETX	-1.470***	-0.138**	URB	-3.068**	-6.291***
	(0.506)	(0.490)		(0.630)	(0.073)		(1.102)	(1.49)
MTP_Avg		1.464*	MTP_Avg		0.102**	IVA	-0.532*	-1.040*
		(0.812)			(0.003)		(0.226)	(0.501)
IMPT_Avg		-1.610***	IMPT_Avg		0.200*	MPRE_Avg		1.093*
		(0.454)			(0.082)			(0.764)
GFN_Avg		-3.760***	RD_Avg		0.860	MTW_Avg		0.067
		(1.157)			(0.824)			(0.081)
ECI_Avg		2.281***	TGL_Avg		0.310**	MTE_Avg		-0.035**
		(0.848)			(0.007)			(0.011)
TGL_Avg		1.015*	GFN_Avg		3.501**	GFN_Avg		2.125
		(0.795)			(1.472)			(3.402)
			ETX_Avg		2.582*	EGL_Avg		0.119*
					(1.512)			(0.073)
						URB_Avg		-9.374
								(19.87)
						IVA_Avg		-1.083***
								(0.091)
c_d_p	0.890***			1.030***			1.005***	
	(0.202)			(0.159)			(0.121)	
_CONS	41.31***	-311.1***		27.18***	-1.157		-31.195	65.009
	(21.91)	(76.41)		(1.968)	(3.215)		(72.16)	(69.952)
RMSE	5.1294	**4.8334**		0.031	**0.0202**		0.2161	**0.154**
Wald Chi2	68.73***	12.07**		310.45***	61.42***		93.15***	45.43***

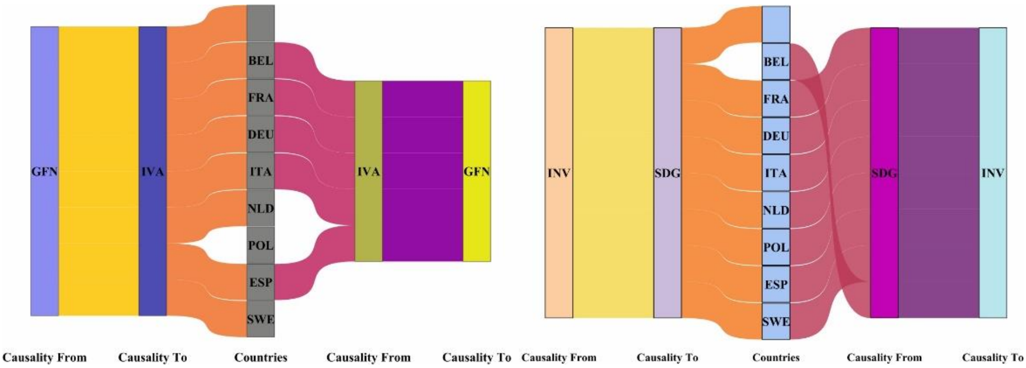
*Note: Standard errors in parentheses, * p < 0.05, ** p < 0.01, *** p < 0.001 and the suffix avg is used to indicate cross-section averaged regressors.*

4.4 Result of causality test

The results from the bootstrap panel causality from GFN to IVA and from IVA to GFN are shown in Table A form green innovations (INV) to SDG and from SDG to INV in Table B in the appendix. The results from Table A reveal two-way causality between IVA and GFN for BEL, FRA, DEU, ITA, and ESP. Moreover, one-way causality is found between GFN and IVA for AUS, NLD, and SWE. This shows strong evidence of causality between GFN and IVA in the selected European countries. This finding shows the importance of green finances in promoting industrial value addition in Europe.

The results from Table B in the appendix reveal two-way causality between INV and SDG in FRA, DEU, ITA, POL, ESP, and SWE. Furthermore, a one-way causality is found between INV and SDG for AUS, EST, HUN, LTU, LVA, NOR, and SVK. Also, a one-way causality is found between INV and SDG for AUS and between SDG and INV for BEL. This shows strong evidence of causality between INV and SDG in Europe. This causality emphasizes the interconnectedness of green innovations and technologies and the attainment of sustainable development goals. This emphasizes the need for clean technologies in production and consumption to mitigate climate change menace and attain long-term sustainability effectively. Figure 1 visually depicts the Granger causality link of variables considered for selected European countries.

Figure 1: Causality outcomes in visual form



This study focuses on the role of green financing strategies and policy interventions in promoting sustainable development in Europe with a specific focus on industrial optimization. The study examines how various factors like industrial green innovation, eco-technology imports, green finances, water and wastewater green technologies, energy-related green technologies, environmental policy, and environmental taxes affect production-based emissions, industrial value addition, and sustainable development goals in 9 largest European countries from 2000 to 2022. By employing various statistical tests such as CIPS for unit roots, second-generation tests for cross-sectional dependence, the CCEMG and AMGE for parameter estimation, and the Bootstrap Granger Causality test for causality analysis, this study presents strong evidence of the efficacy of these green financing strategies and policies.

The findings of the current work demonstrate the significant impact of green strategies and policy interventions on reducing PBE and promoting IVA in Europe. These measures have also contributed to progress towards sustainable development goals. The implementation of green technologies can achieve SGD, the importation of eco-technology, and the enforcement of strict environmental policies and taxes. This has not only resulted in a more sustainable approach but has also enhanced industrial productivity. The findings demonstrate the significant and positive effects of these strategies on the desired outcomes. In conclusion, this research highlights the effectiveness of green strategies and policy interventions in reducing PBE in Europe. Moreover, green finances or investment in green technologies have had the maximum impact on reducing harmful industrial emissions. Therefore, investment in green technologies is strongly recommended. However, challenges such as energy consumption in industries and trade globalization pose obstacles to emission reduction efforts. Moreover, while various factors like industrial innovation and financial investments contribute to IVA, environmental taxes exhibit an inverse relationship with IVA. Additionally, the study shows the importance of green technologies and investments in water and energy sectors in achieving SDGs. However, the negative impacts of economic globalization, urbanization, and IVA on SDG have been noticed. Furthermore, the integration of green production and energy technologies enhances both IVA and SDG attainment.

The findings recommend that European policymakers increase their investments in green technologies and sustainable practices across all sectors. This study also highlights the importance of ongoing support for green innovations. The strengthened environmental policies and the adoption of environmental taxes are also recommended to achieve lasting sustainability. With a focus on these key areas, Europe can continue to lead the way in global sustainability. It can also decrease its impact on the environment and promote industrial growth in an eco-friendly manner.

Strengthening green strategies and policies to reduce PBE is strongly recommended. Moreover, addressing energy consumption and trade globalization through promoting energy efficiency and sustainable supply chain practices is also desirable. Promoting sustainable industrial growth by encouraging R&D and incentivizing the adoption of green technologies is necessary to achieve the objective. Furthermore, urban planning with environmental conservation efforts is also required. Also, the adoption of green technologies and incentivizing collaboration between industry, academia, and government is required. These policies aim to leverage Europe's strengths in innovation and sustainability to address environmental challenges and advance towards a more environmentally friendly and prosperous future.

There are a few limitations of the current work. It is important to consider the potential variability in the implementation and effectiveness of green strategies and policies across different European countries. Another limitation is the dependence on past data. It might not completely reflect upcoming trends or advancements in technology. Finally, it is important to note that the study focuses solely on Europe, so the results may not be directly relevant to other regions because every region has distinct economic and environmental circumstances and related solutions.

Appendix:

Table A: Results of bootstrap panel causality

	From GFN to IVA					From IVA to GFN			
	Estimate	Std. Error	t value	Pr(>|t|)		Estimate	Std. Error	t value	Pr(>|t|)
AUS	9.570	4.876	1.963	0.065	AUS	-0.015	0.016	-0.920	0.369
BEL	17.43	6.394	2.727	0.013	BEL	-0.032	0.014	-2.390	0.027
FRA	20.97	8.338	2.515	0.021	FRA	0.802	0.080	10.07	0.000
DEU	0.911	0.073	12.51	0.000	DEU	0.929	0.042	22.18	0.000
ITA	0.916	0.040	22.95	0.000	ITA	0.949	0.060	15.74	0.000
NLD	0.876	0.064	13.77	0.000	NLD	-0.014	0.016	-0.875	0.393
POL	7.017	4.279	1.640	0.118	POL	-0.003	0.009	-0.334	0.742
ESP	0.630	0.076	8.254	0.000	ESP	-0.078	0.021	-3.666	0.002
SWE	0.980	0.044	22.28	0.000	SWE	-0.034	0.027	-1.247	0.228

Table B: Results of bootstrap panel causality

	From INV to SDG					From SDG to INV			
	Estimate	Std. Error	t value	Pr(>|t|)		Estimate	Std. Error	t value	Pr(>|t|)
AUS	1.730	2.752	3.112	0.048	AUS	-0.503	0.338	-1.490	0.153

BEL	0.066	0.116	0.569	0.576	BEL	-4.135	0.590	-7.009	0.000
FRA	0.497	0.140	3.545	0.002	FRA	-6.718	1.788	-3.756	0.001
DEU	0.640	0.119	5.370	0.000	DEU	-9.481	3.458	-2.742	0.013
ITA	0.849	0.047	17.941	0.000	ITA	-5.548	1.398	-3.969	0.001
NLD	0.310	0.159	1.958	0.065	NLD	-2.025	0.657	-3.080	0.006
POL	0.546	0.092	5.917	0.000	POL	-3.460	0.764	-4.531	0.000
ESP	0.644	0.104	6.177	0.000	ESP	-1.103	0.360	-3.063	0.006
SWE	0.497	0.100	4.957	0.000	SWE	-0.600	0.164	-3.651	0.002

References

Adeneye, Y.B., Jaaffar, A.H., Ooi, C.A. and Ooi, S.K., 2021. Nexus between carbon emissions, energy consumption, urbanization and economic growth in Asia: Evidence from common correlated effects mean group estimator (CCEMG). *Frontiers in Energy Research*, *8*, p.610577. https://doi.org/10.3389/fenrg.2020.610577

Aghion, P., Howitt, P., Brant-Collett, M. and García-Peñalosa, C., 1998. *Endogenous growth theory*. MIT press.

Ambec, S., Cohen, M.A., Elgie, S. and Lanoie, P., 2013. The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness?. *Review of environmental economics and policy*. https://doi.org/10.1093/reep/res016

Anzolin, G. and Lebdioui, A., 2021. Three dimensions of green industrial policy in the context of climate change and sustainable development. *The European Journal of Development Research*, *33*(2), pp.371-405. https://doi.org/10.1057/s41287-021-00365-5

Baltagi, B.H. and Hashem Pesaran, M., 2007. Heterogeneity and cross section dependence in panel data models: theory and applications introduction. *Journal of Applied Econometrics*, *22*(2), pp.229-232. https://doi.org/10.1002/jae.955

Berman, E. and Bui, L.T., 2001. Environmental regulation and productivity: evidence from oil refineries. *Review of economics and statistics*, *83*(3), pp.498-510. https://doi.org/10.1162/00346530152480144

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

Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of econometrics*, *188*(2), 393-420. https://doi.org/10.1016/j.jeconom.2015.03.007

Cifuentes-Faura, J., 2022. European Union policies and their role in combating climate change over the years. *Air Quality, Atmosphere & Health*, *15*(8), pp.1333-1340. https://doi.org/10.1007/s11869-022-01156-5

De Marchi, V., 2012. Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms. *Research policy*, *41*(3), pp.614-623. https://doi.org/10.1016/j.respol.2011.10.002

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

Eberhardt, M. and Bond, S., 2009. Cross-section dependence in nonstationary panel models: a novel estimator. https://mpra.ub.uni-muenchen.de/id/eprint/17692

Eberhardt, M. and Teal, F., 2010. Productivity analysis in global manufacturing production.https://ora.ox.ac.uk/objects/uuid:ea831625-9014-40ec-abc5-516ecfbd2118

Huang, L., Quddoos, M.U., Akhtar, M.H., Haseeb, A., Khan, M.B. and Rafique, A., 2023. Nexuses between carbon emissions, trade openness, transport services, globalization index, and growth in China: targeting the sustainable development goals. *Environmental Science and Pollution Research*, pp.1-15. https://doi.org/10.1007/s11356-023-30214-3

Jakob, M., Steckel, J.C. and Edenhofer, O., 2014. Consumption-versus production-based emission policies. *Annu. Rev. Resour. Econ.*, *6*(1), pp.297-318. https://doi.org/10.1146/annurev-resource-100913-012342

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, S., Azam, M., Ozturk, I. and Saleem, S.F., 2022. Analysing association in environmental pollution, tourism and economic growth: empirical evidence from the commonwealth of independent states. *Journal of Asian and African Studies*, *57*(8), pp.1544-1561. https://doi.org/10.1177/00219096211058881

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., 2024. 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., Khan, K. and Cifuentes-Faura, J., 2023c. 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., 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., Qayyum, S., Calin, A.C., Saleem, S.F. and Nazir, N., 2022. The role of pricing strategies, clean technologies, and ecological regulation on the objectives of the UN 2030 Agenda. *Environmental Science and Pollution Research*, pp.1-14. https://doi.org/10.1007/s11356-021-18043-8

Khurshid, A., Rauf, A., Qayyum, S., Calin, A.C. and Duan, W., 2023b. Green innovation and carbon emissions: the role of carbon pricing and environmental policies in attaining sustainable development targets of carbon mitigation—evidence from Central-Eastern Europe. *Environment, Development and Sustainability*, *25*(8), pp.8777-8798. https://doi.org/10.1007/s10668-022-02422-3

Kong, D., Xiong, M. and Qin, N., 2023. Tax incentives and firm pollution. *International Tax and Public Finance*, *30*(3), pp.784-813. https://doi.org/10.1007/s10797-022-09731-3

Kónya, L., 2006. Exports and growth: Granger causality analysis on OECD countries with a panel data approach. *Economic modelling*, *23*(6), pp.978-992. https://doi.org/10.1016/j.econmod.2006.04.008

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, R., Wang, Q., Han, X. and Yang, X., 2023b. Trajectory and drivers of China's consumption-based and production-based renewable energy consumption. *Energy Strategy Reviews*, *47*, p.101083. https://doi.org/10.1016/j.esr.2023.101083

Li, Z., Khurshid, A., Rauf, A., Qayyum, S., Calin, A.C., Iancu, L.A. and Wang, X., 2023a. 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

Liu, Q., Deng, X., Wang, B. and Teng, F., 2023. An evaluation of the priority mitigation technology needs of Belt and Road Initiative developing countries. *Ecosystem Health and Sustainability*, *9*, p.0026. https://doi.org/10.34133/ehs.0026

Liu, Z., Kong, L. and Xu, K., 2024. The impact of public environmental preferences and government environmental regulations on corporate pollution emissions. *Journal of Environmental Management*, *351*, p.119766. https://doi.org/10.1016/j.jenvman.2023.119766

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.

Mao, G., Han, Y., Liu, X., Crittenden, J., Huang, N. and Ahmad, U.M., 2022. Technology status and trends of industrial wastewater treatment: A patent analysis. *Chemosphere*, *288*, p.132483. https://doi.org/10.1016/j.chemosphere.2021.132483

Mengxuan, T., Khan, K., Cifuentes-Faura, J. and Sukumaran, S., 2024. Technological innovation and energy efficiency in central Eastern European countries. *Utilities Policy*, *88*, p.101761. https://doi.org/10.1016/j.jup.2024.101761

Munta, M. (2020). The European Green Deal. *Climate change energy and environment*. https://www.researchgate.net/profile/Mario-Munta/publication/344161380

Mwiinde, C. and Munshifwa, E.K., 2024. Urbanization, poverty, and homelessness in Zambian cities: A threat to the achievement of sustainable development goals. In *Homelessness to Hope* (pp.37-51). Elsevier. https://doi.org/10.1016/B978-0-443-14052-5.00003-3

Ojekemi, O.S., Rjoub, H., Awosusi, A.A. and Agyekum, E.B., 2022. Toward a sustainable environment and economic growth in BRICS economies: do innovation and globalization matter?. *Environmental Science and Pollution Research*, *29*(38), pp.57740-57757. https://doi.org/10.1007/s11356-022-19742-6

Pesaran, M.H., 2006. Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica*, *74*(4), pp.967-1012. https://doi.org/10.1111/j.1468-0262.2006.00692.x

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. *Journal of applied econometrics*, *22*(2), pp.265-312. https://doi.org/10.1002/jae.951

Porter, M.E. and Linde, C.V.D., 1995. Toward a new conception of the environment-competitiveness relationship. *Journal of economic perspectives*, *9*(4), pp.97-118. https://doi.org/10.1257/jep.9.4.97

Rauf, A., Bashir, M., Asif, K. and Saleem, S.F., 2018. Impact of health expenditures on labor force participation: evidence from Pakistan. *Asian Journal of Economic Modelling*, *6*(4), pp.419-427. https://doi.org/10.18488/journal.8.2018.64.419.427

Rennings, K., 2000. Redefining innovation—eco-innovation research and the contribution from ecological economics. *Ecological economics*, *32*(2), pp.319-332.https://doi.org/10.1016/S0921-8009(99)00112-3

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

Sungkawati, E., 2024. Opportunities and Challenges: Adopting "Blue-Green Economy" Terms to Achieve SDGs. *Revenue Journal: Management and Entrepreneurship*, *2*(1), pp.01-13. https://doi.org/10.61650/rjme.v2i1.333

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

Wang, M.L., 2023. Effects of the green finance policy on the green innovation efficiency of the manufacturing industry: A difference-in-difference model. *Technological Forecasting and Social Change*, *189*, p.122333. https://doi.org/10.1016/j.techfore.2023.122333

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*, pp.1-15. https://doi.org/10.1007/s11356-021-16208-z

Wolde-Rufael, Y. and Mulat-Weldemeskel, E., 2023. Effectiveness of environmental taxes and environmental stringent policies on CO2 emissions: the European experience. *Environment, Development and Sustainability*, *25*(6), pp.5211-5239. https://doi.org/10.1007/s10668-022-02262-1

Xia, W., Doğan, B., Shahzad, U., Adedoyin, F.F., Popoola, A. and Bashir, M.A., 2022. An empirical investigation of tourism-led growth hypothesis in the european countries: evidence from augmented mean group estimator. *Portuguese Economic Journal*, pp.1-28. https://doi.org/10.1007/s10258-021-00193-9

Xie, J., Chang, Z., Guo, X. and Hämäläinen, T., 2022. Energy efficient resource allocation for wireless powered UAV wireless communication system with short packet. *IEEE Transactions on Green Communications and Networking*, *7*(1), pp.101-113. https://doi.org/10.1109/TGCN.2022.3218314

Zhang, M., Hong, Y. and Zhu, B., 2022. Does national innovative city pilot policy promote green technology progress? Evidence from China. *Journal of Cleaner Production*, *363*, p.132461. https://doi.org/10.1016/j.jclepro.2022.132461