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GREEN FINANCE, RENEWABLE ENERGY, AND ECONOMIC GROWTH: A STRUCTURAL EQUATION MODELLING APPROACH IN EUROPE AND CENTRAL ASIA

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ABSTRACT

The paper investigates the dynamic nature of the relationship between green finance, sustainable development, and economic growth for 48 European and Central Asian countries between 2001 and 2024. The research studies how GDP per capita growth, CO2 emissions per capita, and renewable energy use as a proportion of total final energy use affect the overall balance using direct, indirect, and undirected data. The results show that the negative impact of CO2 emissions on economic growth is very large, which brings out the limits of the environment on efficiency. The direct impact of renewable energy consumption on GDP is not significant, but it has a substantial impact through emission reductions, highlighting the importance of this source in long-term sustainability. The indicators of model fit demonstrate strong specifications, but the average explanatory power may indicate the need to enhance the sustainability proxy. The findings include the importance of green finance, which can have the most significant impact in terms of structural energy transformation and reducing environmental stress, as well as creating a platform for resilient growth. The research can advance the empirical level of sustainability pathways and provide policy implications for promoting short-term trade-offs against long-term development objectives.

Keywords: *Green Finance, Sustainable Development, Renewable Energy Transition, Economic Growth*

Introduction

Economic growth is the sustained increase in the production of goods and services in a country and is a fundamental goal of modern economic policy that has a significant impact on employment, living standards, and financial stability. It summarizes both the quantitative growth rate in GDP and the qualitative growth rate in well-being and human development, by which policymakers analyze economic performance and future prosperity. (Shuyang et al., 2021; Marc et al., 2022; Khalid et al., 2025; Ali et al., 2025). In the contemporary environment, the measurement of economic growth is not based only on its production value but also on how it adheres to environmental sustainability and social well-being, bearing in mind that current growth patterns can be very costly for the environmental sector if they are not checked. (Audi et al., 2021; Chin et al., 2024; Marc & Al Masri, 2024; Siddique et al., 2025; Mehdi et al., 2025; Abbasi et al., 2025; Ali et al., 2025). Researchers have emphasized the importance of incorporating new financial strategies and sustainability functions in changing growth patterns, such that economic growth is accompanied by environmental protection and social development. Indeed, new studies demonstrate the need to look more critically at the interactions between economic growth, environmental finance, and sustainability in the developing global economy. (Marc, 2024; Arshad et al., 2025; Ali et al., 2025; Ammar et al., 2025; Amir et al., 2025; Iqbal et al., 2025; Ali et al., 2025; Farras et al., 2025; Ali et al., 2025; Bukhari et al., 2025; Arshi et al.,

2025; Ali et al., 2025; Sadiq et al., 2023; Soundarrajan & Vivek, 2016).

Although there is a large literature on the determinants of development, there are still many weaknesses in the body of research, particularly with regard to the need to incorporate environmental sustainability as a central development model. While classical theories of development focus on the mobility of capital, technology and labour, they fail to consider the impact of financial innovations that are explicitly intended for environmental purposes on the performance of economies in the long term(Al-Masri & Ibrahim, 2024; Marc, 2024; Batool et al., 2025; Zahid et al., 2025; Rafique et al., 2025; Ali et al., 2025; Umair et al., 2025; Ali et al., 2025; Shaukat et al., 2025; Azizi et al., 2025; Kanwal et al., 2025; Ahmad et al., 2025; Saim et al.,2025; Longston et al., 2025). Furthermore, there has been extensive research on the contribution of financial development to development, but the contribution of green finance as a subset of financial development that seeks to finance projects with positive impacts on the environment has not been widely studied in the development literature(Soundarrajan & Vivek, 2016; Marc & Yu, 2024; Alo et al., 2025; Aman et al., 2025; Naeem et al., 2025; Ditta et al., 2025; Iqbal et al., 2025; Ali et al., 2025; Zafar et al., 2025; Ullah et al., 2025; Rana et al., 2025; Hashmi et al., 2025; Ali et al., 2025). Research such as studies on the causal relationship between green finance and sustainable outcomes indicates a positive relationship, however, there are inconsistencies and gaps in the direction and magnitude of the effects of the relationship across regions and time frames (Audi & Audi, 2018; Ali et al., 2025; Khan et al., 2025; Ali et al., 2025; Karim et al., 2025; Ali et al., 2025; Khalid et al., 2025; Ali et al., 2025). These unresolved questions give reason to believe that the relationship between economic growth, green finance, and sustainable development should be further explored using empirical evidence, especially in emerging economies where environmental and financial demands are intense.

Green finance is defined as financial investments and financial instruments such as green bonds, sustainable credits, and climate-linked investment vehicles that are designed to help fund environmentally friendly projects and prevent environmental degradation. The concept has received considerable academic and policy attention as financial institutions and regulators seek ways to align capital flows with environmental agendas, including low-carbon transitions and resource efficiency. (Marc, 2016; Sachs et al., 2019; Ali et al., 2025; Abdullah et al., 2025; Ali et al., 2025). Empirical and bibliometric evidence suggest that green finance helps to increase economic resilience and sustainable growth by mobilizing funds to support renewable energy, energy-efficient infrastructure, and climate mitigation projects, and therefore provides economic activities that reduce environmental externalities. Furthermore, green finance is hypothesized to have both direct investment effects and indirect effects that influence incentives for private and public sectors to shift towards sustainable production and consumption patterns. (Marc et al., 2021; Liu & Wu, 2023; Ali et al., 2025; Kumar et al., 2025; Asharf et al., 2025; Shahi et al., 2025; Khan et al., 2025; Aqeel et al., 2025; Arshad et al., 2025). Nevertheless, regulatory inconsistencies, awareness gaps, and implementation challenges have also been listed in the literature as some of the barriers to the effectiveness of green finance instruments, indicating that the usefulness of green finance instruments requires a thorough analysis of their economic implications. (Chin et al., 2024; Khan et al., 2025; Shahid et al., 2025; Humza et al., 2025; Sattar et al., 2025; Kanwal et al., 2025; Ahmad et al., 2025).

Sustainable development represents a complex paradigm that ensures economic growth with environmental and social inclusion, summarized by the United Nations in the framework of the Sustainable Development Goals (SDGs). Theoretically, sustainable development focuses on international equity in using available resources and claims that economic growth should not be at the expense of the environment and social well-being of future generations. (Sachs et al., 2019; Sabir et al., 2025; Niaz et al., 2025; Khan et al., 2025; Ghauri et al., 2025; Qaisrani et al., 2025; Ali et al., 2025). The fact that it is related to economic growth is due to the recognition that long-term prosperity depends on the sustainable management of resources, the strength of institutions, and the well-being of

society. Studies are able to confirm that sustainable development programs will increase productivity and reduce environmental risks, which will provide a stable and long-term economic growth. However, the literature considers sustainable development as an outcome and not as a process mediating between financial innovation and growth, thus leaving the gap between the sustainability framework and green finance affecting macroeconomic performance. (Abul et al., 2022; Chandran & MC, 2024; Smoleńska & Klooster, 2022; Ali et al., 2025; Ahmad et al., 2025; Khalil et al., 2025; Nasir et al., 2025; Anus et al., 2025).

To prevent the confounding effects of control variables on the true relationship between green finance, sustainable development, and economic growth, it is important to consider control variables. The quality of institutions is a determinant that has a significant impact on the allocation of capital, regulatory performance, and corporate governance performance, which determine sustainability performance and economic performance. The level of education and skills in the form of human capital increases labor productivity and promotes the implementation of sustainable technologies, and also mitigates the conversion of financial innovations into growth(Afzal et al., 2022; Marc et al., 2022; Audi & Ali, 2023). Furthermore, trade openness promotes technology transfer, increases market access, and integrates economies into global value chains, which can accelerate or reduce the impact of green finance and sustainability actions on economic growth. The inclusion of these control variables helps to account for the situation in which the measured effects of key independent variables are not being driven by aggregate economic, structural, or policy-related factors.

Literature review

Afzal et al. (2022) examined the role of green finance, eco-innovation, and creativity as the most important factors in driving sustainable development and reducing CO 2 emissions; most of them are viewed through the lenses of R and D expenditures. According to the authors, once green credit and investments in other financial participants are supported by banks and other players, companies become more likely to prefer cleaner technologies and to increase the share of renewable energy. Eco innovation also renders things greener with the coming in of newer and more efficient low-carbon methods of making things. And innovations are driven by creativity and R&D, creating new ideas and technology solutions. The majority of the studies on this area rely on panel information in such sources as the World Development Indicators and other eco-innovation indexes. As a rule, the outcomes suggest that green finance, renewables, and R&D can be used to reduce emissions, but accelerated economic development can occasionally place additional strains on the environment. This is an ASEAN paper that, covering the data between 2011 and 2019, discovered that both green credit and eco-innovation had a very high long-term impact on reducing CO 2. The authors support this argument with the help of some fancy econometric models, such as panel cointegration and CUP-FM/CUP.

Sadiq et al. (2023) observe that sustainable development is strongly influenced by the role of green finance, eco-innovation, and creativity-driven efforts. Many scholars point out that green finance, particularly in the form of green credit and environmentally focused investments, helps governments and firms finance eco-friendly projects and control carbon emissions. Eco-innovation is viewed as a key factor because it encourages cleaner production processes, efficient resource utilization, and the use of low-carbon technologies. Creativity, commonly measured through research and development (R&D) expenditure, enables organizations to develop innovative solutions to environmental challenges. Most empirical studies in this field rely on macro-level panel data obtained from sources such as the World Development Indicators (WDI) and recognized eco-innovation indices. The overall evidence shows that green finance, renewable energy production, eco-innovation, and R&D activities contribute to reducing CO_2 emissions, while rapid economic growth without proper environmental regulations can increase environmental pressure. Findings from an ASEAN-focused study using annual data from 2011 to 2019 reveal strong long-term effects of green credit and eco-innovation in lowering carbon emissions. The use of advanced econometric techniques further

highlights the importance of financial and innovation-based policies in achieving the Sustainable Development Goals.

Chin et al. (2024) emphasize that Recent literature increasingly focuses on the role of green finance in reducing environmental degradation, especially in developing regions. Scholars argue that large infrastructure projects, such as those under the Belt and Road Initiative (BRI), often promote economic growth but also increase energy consumption and carbon emissions. To address this challenge, green finance has been introduced as a policy tool to support environmentally friendly investments and sustainable infrastructure. Empirical studies suggest that green financial instruments, including green loans and renewable energy investments, help lower CO_2 emissions by encouraging cleaner technologies. Most studies in this area rely on macro-level panel data from the World Development Indicators (WDI) and renewable energy finance databases such as the International Renewable Energy Agency (IRENA). Evidence generally shows that green finance has a negative and significant relationship with environmental degradation, while income growth, urbanisation, and trade openness tend to increase emissions. The BRI-focused study uses annual panel data from 2000 to 2019 covering 31 BRI countries. Using dynamic panel techniques, the findings confirm that green finance significantly reduces CO_2 emissions in the long run. Overall, the literature supports the view that green finance is an essential policy tool for balancing economic growth with environmental sustainability in line with the Sustainable Development Goals.

Smoleńska & Klooster (2022) Examine how the banking sector plays a critical role in addressing climate change, particularly through regulation and supervision. Scholars argue that climate-related risks pose serious threats to financial stability and therefore must be integrated into banking frameworks. Unlike empirical studies that rely on numerical datasets, this study adopts a qualitative and policy-based approach, using EU regulatory documents, supervisory guidelines, and legal frameworks as its main sources of data. The analysis mainly draws on EU initiatives such as the Sustainable Finance Action Plan, Capital Requirements Regulation (CRR), Capital Requirements Directive (CRD), and the Green Taxonomy. The study covers developments and regulatory reforms introduced during the 2018–2021 period, when climate risk became a formal concern in EU banking supervision. The authors explain how climate change is treated as a financial risk within the macroprudential framework and discuss challenges related to risk measurement and uncertainty. The findings suggest that while current regulations aim to green the banking system, they rely heavily on banks' internal risk assessments. Overall, the literature emphasizes that clearer regulatory guidance is needed to align banking practices with climate and sustainability goals.

Debrah et al. (2010) Highlight the growing importance of green finance in promoting sustainability within the building and construction sector, which is a major contributor to energy consumption and carbon emissions. Researchers argue that green financial instruments such as green loans, green bonds, and sustainable investment funds encourage the development of energy-efficient and environmentally friendly buildings. These financial tools help reduce emissions by supporting green construction materials, efficient energy systems, and sustainable design practices. The study emphasizes that access to green finance improves firms' ability to adopt environmentally responsible building technologies. Most empirical evidence in this area is based on secondary data collected from international databases, including the World Development Indicators (WDI), energy efficiency reports, and green finance statistics. The paper uses panel data covering the period from 2003 to 2018 to analyse the relationship between green finance and environmental performance in the building sector. The findings show that increased green financing significantly reduces carbon emissions and energy intensity in buildings. Overall, the literature supports the view that green finance is a key policy tool for achieving sustainable urban development and climate goals.

Khan et al. (2022) Examine the role of green finance in addressing environmental challenges and supporting sustainable development. Scholars argue that green financial policies and investments help reduce environmental degradation by encouraging cleaner production

methods and environmentally responsible economic activities. Many studies emphasize that green finance supports renewable energy development and improves environmental quality by reducing carbon emissions. Empirical research in this area commonly relies on macro-level panel data obtained from the World Development Indicators (WDI) and other international environmental and financial databases. The findings generally show that green finance has a significant negative relationship with CO_2 emissions, indicating its effectiveness in improving environmental sustainability. However, economic growth and energy consumption are often found to increase environmental pressure if not managed properly. The study uses panel data covering the period from 2000 to 2018 to analyse the long-run relationship between green finance and environmental outcomes. Advanced econometric techniques are applied to ensure robust results. Overall, the literature supports the view that green finance is a critical policy tool for balancing economic growth with environmental protection and achieving sustainable development goals.

Chandran & MC (2024) have increasingly focused on understanding how green finance contributes to sustainability by mapping its academic development over time. This study uses a bibliometric approach to systematically analyse green finance literature and identify key themes, influential authors, and research trends. The data were collected from the Scopus database, which is widely recognized for its comprehensive coverage of high-quality academic publications. The final dataset consists of 887 peer-reviewed journal articles published between 1996 and December 2023, written in English. Bibliometric tools such as Biblioshiny and VOS viewer were applied to examine publication growth, citation patterns, collaboration networks, and thematic evolution. The findings reveal that green finance research remained limited in the early years but experienced rapid growth after 2015, with a sharp increase after 2020. Major research themes include carbon emissions, renewable energy, green innovation, and sustainable development. China emerges as the leading contributor to green finance research, followed by several developing economies. Overall, the study highlights the growing importance of green finance as a multidisciplinary field supporting environmental and sustainability goals.

Alharbi et al. (2023) suggest that green finance plays a critical role in accelerating renewable energy development across countries. This global study examines how green finance, measured through green bond issuance, supports renewable energy production in different economic and environmental contexts. The study uses annual panel data from 44 countries covering the period 2007 to 2020, which coincides with the emergence and growth of the global green bond market. Data on green bonds are obtained from the SDC Platinum database, while renewable energy production data are sourced from the U.S. Energy Information Administration (EIA). Additional macroeconomic and financial control variables are collected from the World Development Indicators (WDI). The findings show that green finance significantly increases renewable energy production in both the short and long run. The impact is stronger in countries with higher carbon emissions, greater climate risk exposure, and more developed credit markets. The study also highlights that innovation capacity strengthens the effectiveness of green finance. Overall, the evidence confirms that green finance is a key policy tool for supporting renewable energy expansion and achieving global sustainability goals.

Soundarrajan & Vivek (2016) Discuss green finance as a key foundation for achieving sustainable green economic growth, particularly in developing economies such as India. This study mainly adopts a conceptual and descriptive approach rather than an econometric analysis. The authors rely on secondary data sources, including academic literature, policy reports, government publications, and international frameworks related to green growth and sustainable finance. The discussion draws on experiences from Indian financial institutions, green banking initiatives, and global environmental agreements. The study does not use a fixed numerical dataset but reviews developments and practices in green finance up to around 2014–2015, when green growth policies were gaining attention in India. The literature emphasizes that green finance supports economic growth by channelling funds

toward renewable energy, energy efficiency, and environmentally friendly industries. It also highlights the role of banks, public institutions, and development finance in promoting green investments. The findings suggest that without strong green financing mechanisms, green industries may struggle to expand. Overall, the study concludes that green finance is essential for balancing economic growth with environmental protection and long-term sustainability.

Liu & Wu (2023) examined that green finance and sustainability disclosure play an important role in shaping firm performance, capital markets, and economic development. Most studies in this area rely on firm-level and country-level panel data collected from sources such as sustainability reports, ESG databases, stock market records, World Development Indicators (WDI), and central bank publications. Empirical evidence suggests that firms engaging in green financing instruments, such as green bonds and green loans, often experience improved market valuation and lower cost of capital. Sustainability disclosure is found to reduce information asymmetry by enhancing transparency and investor confidence. Several studies using cross-country data from developed and developing economies report that voluntary and mandatory sustainability reporting positively influences firm value. The reviewed literature generally covers data periods ranging from the mid-1990s to 2019, with many recent studies focusing on the post-2008 financial crisis and post-COVID-19 periods. Long-run panel analyses indicate that green finance supports economic growth while promoting environmental responsibility. However, the literature also identifies challenges related to data consistency, measurement standards, and comparability of sustainability disclosures across countries.

Fu et al. (2023) emphasize that green finance has become a central tool for achieving sustainable development and addressing climate change challenges. This paper adopts a narrative literature review approach rather than using numerical or econometric data. The authors synthesize findings from a wide range of previous empirical and theoretical studies, policy reports, and institutional publications related to green finance and sustainability. The reviewed literature broadly covers studies published from the early 2000s up to 2022, reflecting the evolution of green finance practices over time. The review highlights that green finance supports low-carbon initiatives, renewable energy investment, and climate-resilient development through instruments such as green bonds, green credit, and impact investing. It also emphasizes the importance of ESG integration, regulatory frameworks, and institutional investor involvement. The literature consistently shows that effective green finance policies can reduce environmental risks while supporting long-term economic growth. However, the review also identifies gaps related to data availability, standardization, and implementation challenges. Overall, the study concludes that coordinated financial policies and transparent governance are essential for advancing sustainable development goals.

Ozili et al. (2022) provide strong evidence that green finance plays a critical role in supporting environmental protection and sustainable development worldwide. This study adopts a systematic literature review approach rather than using primary quantitative or econometric data. The analysis is based on secondary sources, including peer-reviewed journal articles, policy reports, and practitioner publications collected mainly through Google Scholar and institutional databases. The reviewed studies largely cover research published from 2010 to 2021, reflecting recent global developments in green finance. The literature highlights key themes such as green bonds, green loans, sustainable banking, regulatory support, and the role of financial institutions in climate mitigation. It also identifies major challenges, including a lack of standard definitions, weak policy coordination, limited investor awareness, and insufficient incentives. Cross-regional evidence indicates that developed economies have more advanced green finance frameworks than developing countries. Overall, the review concludes that green finance has significant potential to support the Sustainable Development Goals; however, stronger policies, improved data availability, and better institutional coordination are required for effective implementation.

Shuyang et al. (2021) examined why green finance is necessary beyond traditional public

environmental spending. This study uses a cross-country panel data approach combined with a theoretical economic growth model to analyse the role of green finance in long-term development. The empirical analysis relies on panel data from 21 countries covering the period 2000–2018. Green finance is measured using corporate debt data of environmentally friendly firms obtained from the Bloomberg database, while government environmental expenditure data are sourced from the United Nations Open Data. Macroeconomic indicators such as GDP, education, inflation, and openness are taken from the World Bank's World Development Indicators (WDI). The findings show that green finance has a significant positive impact on economic growth, whereas government environmental spending exhibits a diminishing effect over time. The study further develops a theoretical growth model to explain why green finance is more effective in supporting long-term, high-quality growth. Overall, the literature suggests that green finance complements public policies and becomes increasingly important at advanced stages of economic development.

Theoretical framework

Endogenous growth theory assumes that economic growth is driven largely by internal factors, including human capital, innovation, and knowledge stocks, rather than external factors, including natural resources or population growth. In contrast to neoclassical models, where investment returns are diminishing, this theory focuses on increasing the returns that are earned through investments in research and development, education, and technology that are not subject to any external shocks, thus ensuring long-term growth. The implications for green finance are that green innovations, such as renewable energy technologies or sustainable agriculture, should be supported by funding that establishes itself as endogenous, can increase productivity and efficiency, and reduce environmental degradation. Overall, endogenous growth theory offers an impressive framework for long-term expansion in a resource-constrained world(Liu & Wu, 2023).

The Triple Bottom Line (TBL), introduced by John Elkington, is a model that encourages a balance between the three pillars of people (social equity), planet (environmental protection), and profit (economic viability) to achieve true sustainability. It is a critique of more traditional and profit-focused models that claim that in order to be successful in the long term, it is necessary to incorporate social and environmental metrics into business and policy decisions. TBL in green finance helps investors invest in projects with multi-dimensional benefits, including reducing carbon emissions, creating jobs, and improving community well-being (Chin et al., 2024). Empirical use shows that TBL has been effective in assessing green bonds, whose returns are measured not only in financial terms but also in ESG (environmental, social, governance) terms. The theory focuses on accountability, where firms are required to report on all three lines to attract ethical investors. Issues such as measuring social and environmental outcomes are not easy, but can be addressed by integrated reporting. TBL also encourages circular economies in which waste reduction improves efficiency and growth. In terms of policymaking, it favors green finance incentives to bridge the economic and environmental divide. Finally, TBL reinvents success, with sustainability as one of its central value creation methods.

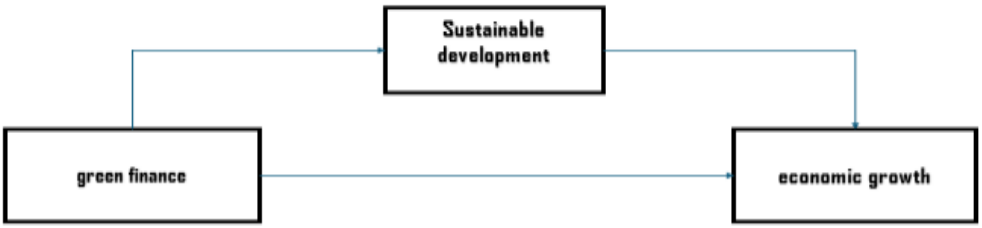


Figure 1: structure diagram

Econometric Methodology

The methodology used in the econometric analysis of this study is panel data analysis that empirically tests the mediating variable of sustainable development (SD) in the relationship between green finance (GF) and economic growth (EG). The sample used is panel data of selected countries (or provinces) over a period [e.g., 2010-2023] based on reliable databases such as the World Bank, national statistics, or the Green Finance Index. Such variables as GF (proxied by green bond issuance or green credit ratio), SD (measured by the SDG Composite Index or Environmental Performance Index), EG (real GDP growth rate), and controls such as GDP per capita, government spending, industrial structure, human capital, and trade openness are used. The data are log-transformed where necessary, winnowed in the case of outliers, and tested for stationarity (e.g., Levin-Lin-Chu test) and multicollinearity (VIF < 10). The mediation model takes a modified Barr and Kenny (1986) design in a panel context, but with more sophisticated methods for dealing with endogeneity, heterogeneity, and dynamics. The baseline model estimates the overall effects of GF on EG through a fixed-effects regression:

$$EG_{it} = \beta_0 + \beta_1 GF_{it} + \gamma X_{it}$$

and Xit represents the controls, mi entity fixed effects, and lt time fixed effects (where the Hausman test is used to select FE vs. RE). In the case of mediation, SD is regressed at the first step.

$$SD_{it} = \alpha_0 + \alpha_1 GF_{it} + \delta X_{it}$$

Expectation a_1 > 0 and significant. The second step involves adding GF and SD to the EG equation:

$$EG_{it} = \theta_0 + \theta_1 GF_{it} + \theta_2 SD_{it} + \phi X_{it}$$

To overcome the rigidity of Baron and Kenny and their limitations (e.g., low power, normality assumption), bootstrapping (with 5,000 replicates) is used to provide confidence intervals for the indirect effect, or the Sobel test is used to provide asymptotic significance. Structural equation modeling (SEM) provides simultaneous estimation of all paths, measures model fit through indices of CFI > 0.95, RMSEA < 0.06, and TLI > 0.95, and provides management of potential measurement error in the composite indices. To achieve power, the generalized method of moments (GMM) deals with endogeneity and persistence in growth dynamics (Blundell and Bond, 1998). Other tests include quantitative regression of the heteroskedastic effects at different levels of growth, instrumental variables (e.g., lagged GF or policy instruments), sub-sampling by region/income, and sensitivity tests using alternative proxies. Robust standard errors clustered at the entity level in all estimates address the issue of heteroskedasticity and autocorrelation, which means that it is appropriate to estimate the direct and indirect relationships within the green finance-sustainable development-economic growth nexus.

Research Methodology

The current study follows a quantitative research design and uses balanced panel data on 48 countries in Europe and Central Asia between 2001 and 2024. The proxy for economic growth is the growth in GDP per capita (annual percentage), the proxy for green finance is the ratio of sustainable development and renewable energy consumption to total final energy consumption, and the proxy for the mediating variable is defined as CO2 emissions per capita. These proxies were chosen based on the need to be able to analyze them cross-country and longitudinally, along with the data at hand and their conceptual relevance. The data were made available in internationally recognized databases to ensure reliability, consistency, and comparability across samples.

Structural equation modeling (SEM) was used to estimate the hypothesized relationships between constructs, as it enables the simultaneous determination of direct, indirect, and cumulative effects. SEM was chosen due to the model's ability to explain complex causal mechanisms and mediating effects, which is a key point of research design in the relationship between green finance, sustainable development, and economic growth. Model fit was measured using standard indices such as RMSEA, CFI, TLI, and SRMR, and goodness of fit was compared using the formulas of AIC and BIC. Measurement and structural components are included in the specification, and this ensures construct validity and eliminates potential endogeneity issues. This methodology

provides a rigorous empirical basis for investigating the impact of green finance on sustainable development in Europe and Central Asia using per capita indicators of structural energy distribution.

Discussion, Results, and Analysis

This section provides the empirical evidence obtained as a result of the research and explains it in the framework of sustainable development and economic growth. The analysis will be aimed at outlining the connections between the chosen variables, and the findings will support both the direct and mediated relationships. The discussion then contextualizes these results in the current literature, paying attention to both areas of convergence and divergence with previous literature. The analysis, results, and discussion, in their combination, provide the full picture of the interactions between green finance and environmental sustainability, as well as economic performance in European and Central Asian countries.

Table 1: Descriptive Statistics

```
. summarize gdp co2_emission energy_consumption, separator(8)
```

Variable	Obs	Mean	Std. Dev.	Min	Max
gdp	1,152	2.946745	4.927734	-29.1	43.69
co2_emission	1,152	6.446389	3.501921	.33	25.6
energy_con~n	1,152	20.12955	16.52483	.05	83

The Fig: descriptive statistics indicate there is a significant difference among the three variables. The growth of GDP per capita has a standard deviation that is fairly large (4.93) and an average value of 2.95 per cent, which shows that there is a lot of variation in the growth of the value of GDP across countries and years, with extreme values of -29.1: severe contraction to 43.69: rapid expansion. The average amount of CO 2 emissions is 6.44 metric tons, and the dispersion (SD = 3.50) indicates the variations in industrial systems and reliance on energy, ranging between very low (0.33) and incredibly intensive economies (25.6). The consumption of renewable energy is at 20.13% of total final energy consumption, with a wide variation (SD = 16.52), with a minimum of 0.05 and a maximum of 83, respectively. These findings indicate the heterogeneity within the economic performance, environmental pressures, and energy transition among the 48 European and Central Asian countries, and therefore the need to model both the direct and mediated impacts within the SEM framework.(Smoleńska & Klooster, 2022).

Table 2: Correlation Matrix

```
. correlate gdp co2_emission energy_consumption
(obs=1,152)
```

	gdp	co2_em~n	energy~n
gdp	1.0000		
co2_emission	-0.1351	1.0000	
energy_con~n	-0.0294	-0.3555	1.0000

The correlation matrix shows that there are rather weak associations between the three variables. There is a weak negative relationship between GDP growth and CO 2 emissions (-0.135), indicating that the correlation between an increase in CO 2 and sluggish growth is weak. The consumption of renewable energy is also negatively related to the emission of CO 2 (-0.356), as it is expected that increasing the use of renewable energy sources lowers the carbon intensity. Its relationship with the GDP growth is extremely low (-0.029), which means that it does not have a significant direct impact on the economic performance. In general, the findings suggest focusing on the indirect and mediated impacts because direct correlations might not be able to capture the influence of green finance on sustainable growth.(Khan et al., 2022).

The estimated structural equation model was fit on maximum likelihood based on 1,152 observations, and the log likelihood was stable at -11322.207 after all the iterations, which means

convergence. The development of GDP per capita is taken as an endogenous variable, which is determined by CO 2 emissions and renewable energy usage. The negative value of the CO 2 emissions coefficient (-0.234, p < 0.001) is important and significant, indicating that increasing the level of economic growth is strongly connected with a decrease in emissions. The impact of renewable energy consumption on GDP is also negative but less significant (–0.026, p = 0.004), which means that structural energy transition could, at the start, limit its growth, perhaps because of adjustment costs. To the mediator, the consumption of renewable energy can greatly cut the emissions of CO 2 (0.000075, p 0.001), meaning that green finance is beneficial to the environment. Constants in the two equations are positive and can be interpreted as the levels of GDP growth and emissions at a given time that do not depend on the predictors. The error term estimates (23.65 of GDP, 10.70 of CO 2) imply the existence of a large amount of heterogeneity in the countries and years, which are not explained by the model. On the whole, the model shows that renewable energy has statistically significant indirect facilitating effects, such as reducing emissions, despite a moderately negative effect on GDP(Sachs et al., 2019). This highlights the need to account for direct and mediated impacts in determining the contribution of green finance to sustainable development.

Table 3

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
gdp						
co2_emission	-.2343915	.0437958	-5.35	0.000	-.3202296	-.1485534
energy_consumption	-.0264107	.0092811	-2.85	0.004	-.0446014	-.00822
_cons	4.98936	.4155042	12.01	0.000	4.174986	5.803733
co2_emission						
energy_consumption	-.0753357	.0058359	-12.91	0.000	-.0867738	-.0638976
_cons	7.962863	.1519604	52.40	0.000	7.665026	8.2607
var(e.gdp)	23.65249	.9855206			21.79768	25.66514
var(e.co2_emission)	10.70435	.4460145			9.864919	11.61521

LR test of model vs. saturated: chi2(0) = 0.00, Prob > chi2 = .

The direct effects table indicates that there are statistically significant correlations between the three variables. CO2 emissions have a significant adverse effect on the growth of the GDP (-0.234, p < 0.001), and their increased level is always linked to the declining economic performance. The consumption of renewable energy also exerts a negative impact on the GDP growth (0.026, p = 0.004), but the impact is smaller, which argues in support of transitional costs or structural changes in the economies inclined to renewables. Simultaneously, the use of renewable energy has a considerable effect on the CO 2 emission (-0.075, p =0.001), which proves its contribution to alleviating the environmental strains. The coefficients are all negative, as they indicate trade-offs between growth, emissions, and energy transition.(Sachs et al., 2019). The findings underscore the need to factor in the indirect effects since the environmental benefits of renewable energy might eventually be useful in supporting sustainable growth in spite of the fact that it has a small direct restraint on GDP.

Table 4

Direct effects

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
gdp						
co2_emission	-.2343915	.0437958	-5.35	0.000	-.3202296	-.1485534
energy_consumption	-.0264107	.0092811	-2.85	0.004	-.0446014	-.00822
co2_emission						
energy_consumption	-.0753357	.0058359	-12.91	0.000	-.0867738	-.0638976

The indirect effects table shows the mediating effect of CO2 emissions between renewable energy consumption and GDP growth. Renewable energy consumption has a statistically significant indirect effect on GDP (0.0177, $p < 0.001$), which means that the effect of the former does not directly affect growth but is mediated by the reduction in emission levels. This channel indicates that renewables may cause short-term structural costs to GDP, but their environmental benefits indirectly complement economic efficiency through the reduction in carbon intensity. The lack of alternative indirect pathways confirms the fact that CO2 emissions are the only mediator in the scheme. In general, it can be said that the results support the relevance of considering both direct and mediated channels because the indirect effect strengthens the argument in favor of renewable energy as an engine of sustainable growth in the long term.

Table 5

Indirect effects

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
gdp						
co2_emission	0	(no path)				
energy_consumption	.017658	.0035717	4.94	0.000	.0106576	.0246584
co2_emission						
energy_consumption	0	(no path)				

The cumulative overall effect table reveals that CO 2 emission continues to have a strong negative effect on GDP increase (-0.234, $p < 0.001$), which supports their status as one of the major inhibitors of economic performance. The overall impact of renewable energy consumption (-0.009) on the GDP is statistically non-significant, implying that its effects achieve their goals primarily through the indirect channels, but not the direct growth effects. Meanwhile, the consumption of renewable energy will greatly decrease CO 2 emissions (-0.075, $p = 0.001$), which proves the effectiveness of renewable energy in reducing environmental pressures. In general, the findings can be summarized as showing that green finance is associated with sustainable growth through the reduction of emissions, and not direct cross-linkage with the economy.

Table 6

Total effects

	OIM Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
gdp						
co2_emission	-.2343915	.0437958	-5.35	0.000	-.3202296	-.1485534
energy_consumption	-.0087527	.0087821	-1.00	0.319	-.0259652	.0084598
co2_emission						
energy_consumption	-.0753357	.0058359	-12.91	0.000	-.0867738	-.0638976

The fit statistics show an extremely well-specified model. The value of RMSEA 0.000 with 90% confidence also 0.000 indicates that there is no approximation error, and the pclose 1.000 indicates an excellent fit. The fact that comparative indices (CFI = 1.000, TLI = 1.000)

are positive indicates that the model fits the data much better than the base model. The SRMR = 0.000 suggests that there are few residuals, which strengthens the correctness of the specification(Simon & Ulrich, 2018). Despite the fact that the measures of AIC (22658.41) and BIC (22693.76) are used to select the comparative model, it is less informative since their absolute values do not imply other specifications. The coefficient of determination (CD = 0.132) presents a moderate level of explanatory power, which means that though the model fits well statistically, a lot of variance cannot be explained. Altogether, the findings prove the high levels of internal consistency and strength of the SEM framework.

Table 7

Fit statistic	Value	Description
Likelihood ratio		
chi2_ms(0)	0.000	model vs. saturated
p > chi2	.	
chi2_bs(3)	184.926	baseline vs. saturated
p > chi2	0.000	
Population error		
RMSEA	0.000	Root mean squared error of approximation
90% CI, lower bound	0.000	
upper bound	0.000	
pclose	1.000	Probability RMSEA <= 0.05
Information criteria		
AIC	22658.414	Akaike's information criterion
BIC	22693.759	Bayesian information criterion
Baseline comparison		
CFI	1.000	Comparative fit index
TLI	1.000	Tucker-Lewis index
Size of residuals		
SRMR	0.000	Standardized root mean squared residual
CD	0.132	Coefficient of determination

To conclude, the results, discussion, and analysis of the article illustrate how green finance, sustainable development, and economic growth are all intertwined in Europe and Central Asia. Although the proportion of energy used through renewable energy does not have a high impact on the GDP, its considerable effect on the CO 2 emission reduction process demonstrates the value of indirect modes in long-term sustainability(Abul et al., 2022). These results support the idea that the underlying principle of the green finance-induced environmental improvement is eventually the establishment of sustainable economic performance, despite the possible short-term trade-offs.

Conclusion and Recommendations

This paper has discussed how the three variables, namely green finance, sustainable development, and economic growth, are interlinked in 48 European and Central Asian countries between 2001 and 2024 through structural equation modeling. The results indicate that CO 2 emissions have a strong negative influence on the growth of GDP, which indicates the limitation of the environment on the performance of the economy. Although the consumption of renewable energy has a slight negative direct impact on the GDP, it has a significant mitigating effect on emissions, which is why it indirectly leads to the growth of the economy. The findings point to the fact that

both the direct and mediated routes need to be taken into account when examining the role played by green finance in determining long-term developmental outcomes. Although the model fit statistics are excellent, the explanatory power is moderate, which is due to the multidimensionality of sustainability that cannot be well explained in a limited group of proxies. On the whole, the discussion proves the fact that green finance has the best manifestation in the language of a structural transition mechanism, which will decrease environmental pressures and set the condition of sustainable economic development, despite possible short-term trade-offs.

Following these findings, some important recommendations are posed to the policymakers and stakeholders. First, governments need to focus on increased investment in renewable energy that is aimed at both environmental goodwill and enhancing the indirect mechanisms that promote long-term financial development. Second, policy frameworks need to meet transitional costs: they should offer incentives, subsidies, and technological assistance to alleviate the short-term restriction of energy restructuring. Third, sustainability indicators in the future should capture the multidimensional aspect of the SDGs by integrating broad indicators of sustainability such as quality of governance, social inclusion, and energy efficiency. Fourth, there should be increased regional cooperation in Europe and Central Asia to align the green finance policies, exchange technological solutions, and lessen the differences in the capacity to transition to a sustainable and energy-only economy. Lastly, it is recommended to incorporate dynamic modeling methods and longer-term datasets to have better feedback loops and nonlinear effects. Together, these efforts will see green finance developed to be more than an environmental instrument into a wholesome agent of sustainable and inclusive economic growth.

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