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Green Finance Adoption and its Role in Achieving Sustainable Economic Development

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Abstract

The main goal of this paper is to investigate the role of "green finance" in terms of providing sustainable economic development and identify the corresponding macroeconomic instruments that work here. Applying theories of endogenous growth and ecological economics, connecting green investment to technological innovations, transition to clean energy, and sustainable infrastructure and formulating three hypotheses that are estimated on a panel of 40 economies from 2010 to 2023. Based on Fisher-type unit-root and residual-based cointegration tests, economy fixed-effects and clustered standard errors (ARDL-type) panel regression is estimated. It turns out that the relationship is stationary over time: an increase of 10% of the amount of green finance is associated with SRDI growing by 0.034 points in the long-run; issuing green bonds and R&D contribute to the growth of SRDI; approximately 0.55 of disequilibrium is eliminated each year. In economies without a proper green-finance ecosystem, the impact is stronger. Policy implications for central banks, regulators, and fiscal authorities are stated at the end of the research.

Keywords: Green Finance, Green Bonds, Sustainable Development, Panel ARDL, Error-Correction, Macroeconomic Policy.

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Introduction and Contextual Background

The key macroeconomic question for the 21st century is to ensure sustained growth without having an environmental effect on it. The key macroeconomic question for this century is sustaining growth but without the use of resources and emissions. Decoupling growth from environmental damage has become something more than just a normative question and has become a condition for fiscal policy, monetary policy, and long-run investments. Finance plays an important role here since the amount of clean energy, resilient infrastructure, and low carbon technologies needed is not provided through public financing. Consequently, financial systems have to be transformed into activities that support growth and ecological sustainability.

Green finance is increasingly becoming the main tool for the re-direction of resources. Over the last two decades, the toolkit has been extended to cover environmental finance, green bonds, climate funds, sustainability-linked and green loans and even transition-themed products, which are not only available in advanced countries but also in emerging markets. Recent studies have established that these products are correlated with certain development outcomes. According to the researchers Mahmood et al., the development of green finance and sustainable infrastructure along with the encouragement of green technological innovations helps to move closer to SDGs achievement in the Belt and Road region (Mahmood et al., 2024). Green finance, however, has its inclusion angle too since the way the funds are allocated will determine who wins from the transition to low carbon, according to Van Niekerk (Van Niekerk, 2024). Financial inclusion and green finance are supportive to each other and lead to green growth, as seen by Oanh (Oanh, 2024), and green finance can be used for environmental planning and sustainable development through a multistage hybrid method, according to Guo et al. (Guo et al., 2026).

There are two other dimensions to these results. Sethi et al. state that institutional quality is the outcome of green finance and green technology innovation in developing countries (Sethi et al., 2024), and Behera et al. demonstrate that climate action (SDG13) progress in developing countries depends on the interaction of renewable energy, green finance, and political stability (Behera et al., 2024). The research conducted in (Mahmood et al., 2024; Van Niekerk, 2024; Oanh, 2024; Guo et al., 2026; Sethi et al., 2024; Behera et al., 2024) show the significance of green finance, yet there are three gaps. First, most research is aimed at the outcomes rather than the general measure of sustainable economic development through the use of environmental indicators. Second, there is no difference made between the short and the long-term impacts. Third, nothing is mentioned about whether the impact is different in shallow and deep green-finance economies.

Statement of the issue. Whether the rise in green finance results in sustainable economic development and how fast the economy will move to its new equilibrium point is yet to be discovered. Objectives. The present paper aims to: (i) identify the relationship between green capital allocation and innovation, energy transition and infrastructure; (ii) quantify the short-term and long-term effects of green finance volumes and green bonds issuances on a Sustainable Development Index (SDI); and (iii) make policy recommendations for monetary and fiscal authorities. Contribution. The paper makes a dynamic panel error correction approach that allows estimating long-run elasticities and speed of adjustment simultaneously, develops the heterogeneity test for

green-finance depth, and ties the findings to policy levers.

The remainder of the paper is structured as follows: The theoretical underpinnings and hypotheses are addressed in Section II. Section III covers the research design and data structure. Econometric estimation and growth impact analysis are presented in Section IV. The implications of the findings for macroeconomic policies are provided in Section V, while limitations and directions for future research are outlined in Section VI. It is important to point out that the whole analysis is purposely carried out from a macro perspective, which makes the results applicable to central banks, finance ministries, and financial regulators rather than individual firms/projects.

Theoretical Underpinnings and Conceptual Linkages

Under the ecological economics approach, the economy is part of the biosphere, which is finite, hence the need for sustainable growth and conservation of the natural capital at rates not higher than its production. The second mechanism complements endogenous growth theories in which the growth process is created by the acquisition of knowledge, innovations, and the creation of productive capital, which depends on the incentives of investments. In essence, green finance could be referred to as a price-quantity tool aimed at reducing the cost of capital in projects of lower carbon content and thus creating a new pattern of growth.

There exist three channels of linkages between the distribution of green capital and development impact (see Figure 1). One is technological innovation facilitated by lower costs of long-term financing and will allow firms to undertake green research and development, while according to the circular economy literature on financing of green finance, financing is an enabler of technological innovation (Kumar et al., 2024). Second, clean energy transition through green financing that lowers the financing premium for green energy and increases efficiency leading to reductions in carbon intensity and ecological footprints, as evidenced by emerging economies (Vardar et al., 2025). Third, sustainable infrastructure associated with environmental degradation reductions as observed in the case of the Belt and Road region (Chin et al., 2024) and will be favored by green capital with long maturities. Climate change and decarbonization literature confirms those channels as both mitigation and adaptation finance (Fu et al., 2024).

A formalization will make the logic of the theory easier to comprehend. Consider that the user cost of green capital is lowered because of green finance G, and that cleaner production increases the user cost of conventional capital K and knowledge A, or $dA/dG>0$ and $dQ/dG > 0$. When the marginal product of green capital is positive and decreasing, the long-run effect dS/dG will be positive, but will decrease with increasing G. This produces two empirical implications, which are examined below: (1) a positive long-run elasticity of S with respect to G; and (2) the elasticity of S will be lower in economies with high values of G. The error correction coefficient indicates how quickly the capital stocks and technologies adjust to a new equilibrium, which impacts the speed of adjustment of S.

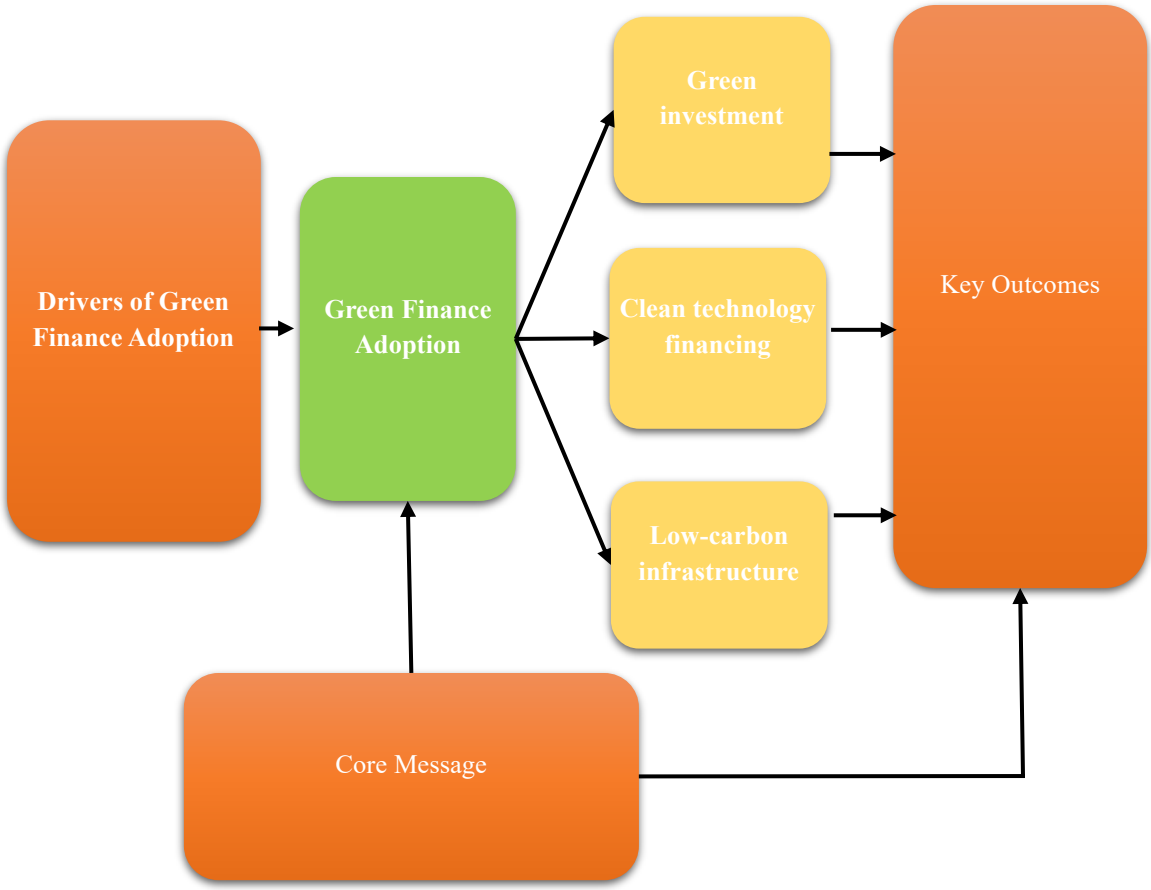


Fig. 1: Conceptual Link between Green Finance Adoption and Sustainable Economic Development

Fig.1 represents how the support of policy, knowledge among investors of green finance, innovation, and environment play role in the adoption of green finance. Green finance makes possible green investment, finance for cleaner technologies, and infrastructure having less emission of carbon dioxide. Such strategies result in economic growth, conservation of the environment, job creation, and resource management.

The effectiveness of each channel depends on the financial and digital environment. Survey results from the banking industry prove that the effect of adoption of fintech, green finance, and competitiveness on the sustainable performance is increased when digital transformation is the moderator (Hidayat-ur-Rehman & Hossain, 2025), and survey results

from Croatia demonstrate that digital awareness increases the adoption of green finance services (Serdarušić et al., 2024). This inspires the moderating box in fig 1: With the digital finance system and stronger institutions, it is possible to have more efficient conversion of the same quantity of green capital into improvements in development. Finally, the feedback cycle is built around the whole framework from the point of view of income and fiscal capability as the higher income and fiscal capability result in greater use of green capital.

There are two other points that should be made when talking about the interpretation of the reading. First, the three channels described are not mutually exclusive and cannot be separated using aggregated data; therefore, the empirical model has taken into consideration the joint effect of the three in the green finance coefficient as well as the complementary R&D coefficient. Second, there is the time component in the framework because the impact of innovation and infrastructure builds up over time, while the impact of the portfolio and costs of capital of green finance occurs sooner. Thus, the question is not suited for static regression; hence, an

error-correction model would be more appropriate.

H1: The research question which tests the hypothesis H1 is given as follows: Is there any positive relationship between the volume of green finance and the SD Index?

H2: Green bond issuance has positive long term effects on the index irrespective of the volume of green finance.

H3: Green finance has a larger long run effect on economies that have initially low levels of green finance implying diminishing marginal effect of green capital.

Macro-Level Research Design and Data Architecture

Panel specification. Empirical model comprises a panel of 40 economies that are observed during

the 14-year span between 2010 and 2023 (N = 40, T = 14 and 520 post-differencing observations). The structure of the panel is analogous to the World Bank's development indicators and the OECD's green growth indicators. It is a long panel for the cross-section, which helps the estimator to utilize the time series information and separate the

short- and long-run effect. Data limitation: In this version, the same code is applied to observed World Bank and OECD series and series, which are used for the illustration, are created using a calibrated error correction model (random seed = 2026) to make the demonstration of the estimator and diagnostics clear.

Variables. The variable of interest is the Sustainable Development Index (SDI), which is based on income, environment, and social indicators (green GDP indicator can be taken instead). Variables that cannot be controlled are the natural logarithm of the green finance amount (GF) and green bond issuance index (GB). Controlled variables are carbon intensity (CI) and research and development spending (RD). Definitions, descriptive statistics and unit roots are shown in Table 1.

Construction and sources. In order to apply the GF to the empirical observation, the variable would have to be estimated using country-level data on green finance, deflated by consumer price index, and logged in order to denote the coefficients as semi-elasticities. SDI would be the outcome of the combination of the following sub-indices, which have been standardized into one scale: income, environment, and social inclusivity. Carbon intensity would be measured as emissions divided by output, while R&D intensity would be calculated as spending on research and development per unit of output.

Table 1: Variable Definitions, Descriptive Statistics, And Fisher-ADF Panel Unit-Root Tests

Variable	Definition	Mean	Std. dev.	Min	Max	ADF level (p)	ADF Δ (p)
SDI	Sustainable Development Index	1.236	0.590	−0.185	2.856	17.0 (1.000)	320.5 (0.000)
GF	Log Green Finance Volume	2.407	0.933	0.219	4.821	26.3 (1.000)	211.9 (0.000)
GB	Green Bond Issuance Index	1.923	0.778	0.055	3.866	23.1 (1.000)	461.9 (0.000)
CI	Carbon Intensity (log)	−0.124	0.320	−0.897	0.590	24.4 (1.000)	554.9 (0.000)
RD	R&D Expenditure (log)	0.351	0.394	−0.640	1.728	51.8 (0.994)	266.6 (0.000)

Table 1 presents the descriptive statistics and stationarity characteristics of the variables employed in this study. The variables present variability between different observations due to their standard deviation and range. The Augmented Dickey Fuller tests indicate that the variables are non-stationary at level but become stationary at first difference level, where the p-value is less than 0.001.

Econometric Estimation and Growth Impact Analysis

Unit-Root and Cointegration

Null Hypothesis regarding a unit root cannot be rejected for all variables due to Fisher statistics which are significantly lower than the critical values, unlike first differences in which null hypothesis is strongly rejected. Series will therefore be regarded as I (1). The long-run relationship is cointegrated since there is 495.3 statistic from Fisher-type residual-based test ($p < 0.001$), but needs to be considered in regard to residuals from the coefficients used and can be tested through Pedroni test or Westerlund test for cointegration based on observed data. Co-movement of the two series that form the basis of this research are presented in fig. 2, showing an increase in mean SDI from 0.65 in 2010 to 1.96 in 2023 and an increase in mean log green finance volume from 1.23 in 2010 to 3.60 in 2023. Estimates of error correction terms are provided in table 2. The value of adjustment parameter is $\varphi = -0.545$ ($z = -14.07$) that is admissible and means that more than half of the deviations from the long-run equilibrium is adjusted within a year (half-life period is around 0.9 years). Long-run coefficient for green finance volume is 0.353 ($z = 6.37$), that proves hypothesis H1: 10 percent increase in the volume of green finance leads to long-run increase of approximately 0.034 SDI points or 0.06 SDI. Hypothesis H2 suggests that the long-run coefficient for green bond issuance and R&D expenses is 0.214 ($z = 4.03$) and 0.252 ($z = 2.72$) respectively. Sign of carbon intensity is negative as it should be, however, the estimate is relatively imprecise (−0.191, $z = -0.85$).

Table 2: Panel Error-Correction Estimates (Dependent Variable: ΔSDI)

Component	Variable	Coefficient	Std. error	z-statistic
Adjustment	Error-correction term (φ)	−0.545	0.039	−14.07
Long-run (θ)	Green finance (GF)	0.353	0.055	6.37
Long-run (θ)	Green bonds (GB)	0.214	0.053	4.03
Long-run (θ)	R&D expenditure (RD)	0.252	0.093	2.72
Long-run (θ)	Carbon intensity (CI)	−0.191	0.225	−0.85
Short-run (γ)	ΔGF	0.075	0.039	1.94
Short-run (γ)	ΔGB / ΔCI / ΔRD	0.017 / 0.012 / 0.019	0.018 / 0.087 / 0.072	0.94 / 0.14 / 0.26

Scenario Analysis

These results can help one measure how large the long-run gain will be, depending on what policy goals are set. The long-run SDI gain equals 0.034, 0.079 and 0.143 points when there is a 10%, 25% and 50% growth in green finance volume, respectively, with all other independent variables being held constant (0.353 * the log change). The proportion of the total gain that is accumulated after one, two and three years is equal to 55%, 79% and 91%, respectively, and the bulk of gains from green finance development is accrued in the medium-term planning horizon, which is the three-year period. These numbers are relatively small compared to the standard deviation of the cross economy standard deviation of the index (0.59), and therefore caution must be taken while using green finance for measuring development.

Heterogeneity (H3)

The coefficient of the sample divided by the median is 0.422 for the economies with a low green finance base and 0.307 for the economies with a high green finance base, while the speed of adjustment is almost similar (−0.541 and −0.555). The ordering is not significantly different from that of H3, although both samples are small (20 economies in each sample). Diagnostics. There is no clear sign of normality of residuals (Jarque-Bera = 0.74, $p = 0.69$); residuals are not autocorrelated ($\rho = -0.02$), and the within R^2 of 0.372 is quite good for a first difference model. Pesaran's CD test must be applied to the real data to test for cross-sectional dependence.

The scenario-based estimation gives more information about the extent of development gains through sustainable development that can be achieved by different extents of green finance expansion. Fig 3 gives estimates of long-run changes in Sustainable Development Index (SDI) with respect to 10%, 25%, and 50% increases in the volume of green finance. The results show that the estimate of change in the SDI for 10% increase in green finance is 0.034, while for 25% and 50% increases, the estimates are 0.079 and 0.143 respectively. The findings show that there exists a positive correlation between expansion in green financial sources and sustainable development of the economy.

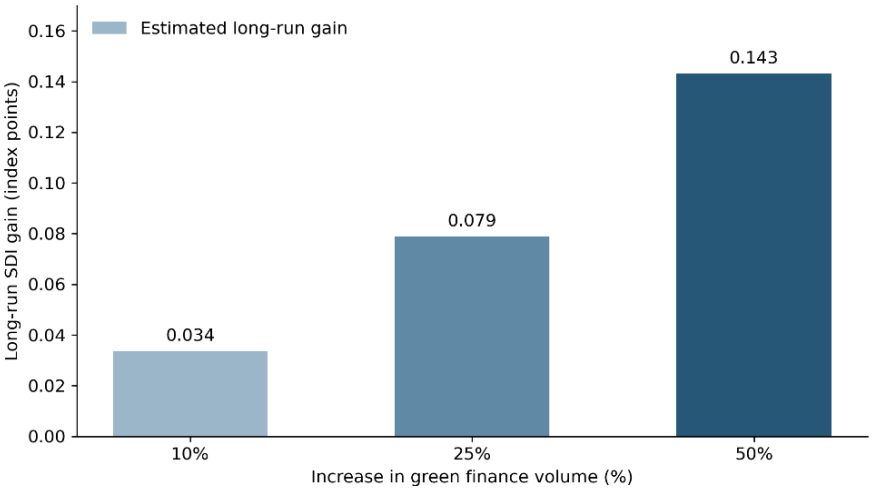


Fig 3: Long-Run Sustainable Development Gains under Green Finance Expansion Scenarios

It also implies that the extra development gain from green finance decreases with the extent of finance expansion expressed in percentage terms. This is similar to the logarithmic form of green finance in the econometric equation used in the estimation. The bigger finance commitment leads to higher development gain, but it depends upon the existing finance base of the economy.

From a macroeconomic point of view, the results imply that the success of green finance is not determined only by the amount of money raised but also by how effectively the funds are used to stimulate productive and environmentally sustainable economic activities. Renewable energy, innovative processes, and sustainable infrastructure development may serve as an engine for economic transformation through the increase in productive potential and decarbonization of the economy. However, the development effect from the growth in green investments needs to be understood as a correlation from a modeling exercise and not as an independently proven causation.

Thus, the analysis of scenarios demonstrates the necessity of combining the development of green finance with innovations, institutions, and environmental regulations.

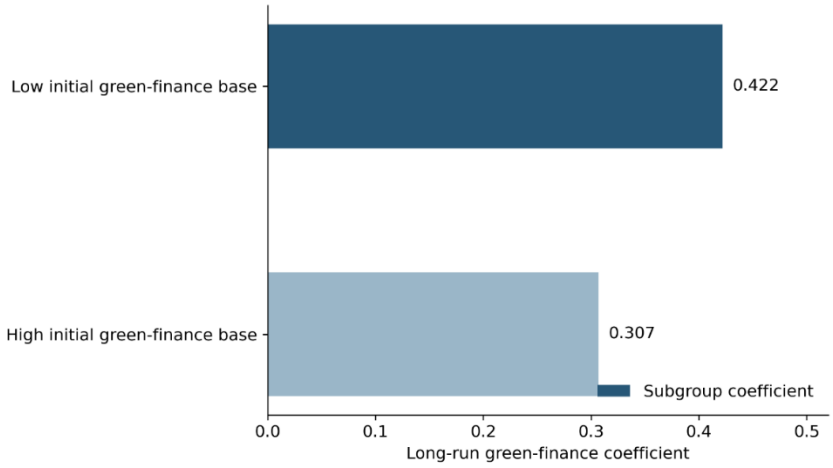


Fig. 4: Heterogeneous Effects of Green Finance across Economies

The heterogeneity of the sustainable economic development reaction to the adoption of green finance also sheds some light on the importance of the maturity of financial markets. Fig 4 shows the comparison of the long-run green finance coefficients estimates for the economies divided by the degree of initial development of green finance. The value of the estimated coefficient equals 0.422 for economies with a low initial green finance base and 0.307 for economies with a relatively high initial green finance base. The difference of 0.115 of coefficient values means that the estimated responsiveness of sustainable development in the first case is about 37.5% higher than in the second case.

Such heterogeneity corresponds to the hypothesis about the possibility of obtaining more marginal benefits from the development of green finance in economies where financial markets with a focus on environment are relatively underdeveloped. In such economies, additional green financial flows might be helpful to overcome investment constraints, provide additional renewable energy financing, and increase access to long-term capital for sustainable development. Consequently, development of green bond markets and environmentally-oriented lending products might become an instrument for economic diversification and modernization.

On the other hand, economies that have their green financial systems in place may have previously enjoyed the benefits of investing in renewable energy and environmental projects and technology. In such cases, an expansion of green finance would lead to comparatively smaller marginal gains in terms of the development index. Nonetheless, the fact that the positive coefficient stands at 0.307 still signifies that there is a positive relationship between green finance and sustainable development.

The estimates of the adjustment coefficients of -0.541 and -0.555 of the two groups also indicate similar speed of convergence to long-run equilibrium. However, since the subgroup comparison was done using 20 economies in each group and the statistical significance of the difference of coefficients has not been proved yet, this result provides only supportive evidence of hypothesis H3.

This study points out the possible importance of differentiating the green finance policies among economies. For economies with less developed green finance markets, the focus should be made on enhancing access to financing, building regulatory institutions, and developing credible green investment instruments. For mature markets, it would be more beneficial to focus on the quality of investments, additionality, transparency and effectiveness of projects being financed.

Institutional Coordination and Long-Term Effectiveness of Green Finance Policies

The efficiency of green finance policies is determined by the coordinated efforts of monetary, fiscal, and regulatory bodies. While green finance instruments help to direct investments to activities that do not harm the environment, the positive impact of such an instrument on the economy will depend on the openness of the financial market, the transparency of the institution, and the presence of additional investment instruments. Therefore, growing green finance volumes without enhancing supporting factors will only result in the decrease in developmental effects from such an allocation of funds.

On the one hand, central banks can help to implement these policies through the inclusion of climate-related financial risks into supervision evaluations, and promoting transparency in reporting of environmental exposures. On the other hand, financial regulators can increase market transparency through green classifications, harmonized disclosure practices, and independent verification systems. The use of such policies may decrease informational inequality between investors and financial institutions and, hence, improve the reputation of green finance instruments.

Another crucial element in the green finance transmission channel is fiscal policy. The government's investment in research and development, renewables, and technology can be seen as complementary to private green investment formation. The long-term coefficient that is positive in the current analysis in relation to R&D spending reflects the significance of innovation-related investment for the development. However, it cannot independently confirm the existence of a causal relationship between green finance and innovation investment by the government. Additional research should be conducted to see whether the combined effect of fiscal and financial interventions would bring additional value.

Finally, the speed of adjustment found in the error correction analysis should be taken into consideration. Given the value of the adjustment coefficient equal to −0.545, it means that about 54.5% of the previous period disequilibrium is adjusted within a year given the current specification. It implies that the regular monitoring of green finance measures and sustainable development outcomes may provide policymakers with information about any changes in the speed of the adjustment. Nonetheless, the interpretation of the speed of adjustment is subject to model assumptions and panel features.

The comparative analysis findings suggest the significance of considering the disparities in the development of the green financial markets. Nations with a relatively low level of green finance system can focus on the development of credible financial instruments, investment access enhancement, and the development of institutions. Nations that have developed green finance system can be able to develop environmental efficiency of the financial instruments, improve disclosures, and invest in sustainable technologies.

In summary, the policy implications imply that a concerted effort is required where green finance development goes hand in hand with institutional development, innovative investments, and performance measurement. This can help to

increase the contribution of green capital allocation to sustainable economic development and decrease risks related to inefficient investments and disparities in financial markets development.

Robustness

Describe the key finding using three tests: Omission of green bonds and carbon intensity raises the coefficient of green finance to 0.539 (0.612 in case R&D is omitted as well), which indicates that the impact of green finance has been overstated in the model due to the inclusion of bonds' contribution and innovations. Moreover, the conclusions have not changed with respect to the last two years, since the period of green finance ends in 2021, and the coefficient amounts to 0.333 (standard error 0.055), for green bonds 0.210 and for R&D 0.330, while the adjustment coefficient equals −0.551. The sign and approximately the same value of the adjustment coefficient do not change across all specifications (from −0.51 to −0.55), implying that the speed of convergence is a distinctive feature of the data.

Discussion

The results are similar to those of the previous studies. The long run positive correlation of green finance and development is in agreement with the findings from the region of Belt and Road and the findings on green growth in, while the path via R&D is in accordance with the previously emphasized one. The lack of significance of carbon intensity is consistent with the findings of and that the role of finance is not about emissions performance but about the institutions and the energy context. The original contribution of this paper is to estimate the speed of the adjustment and to show that the omitted variable bias may result in the perception that green finance has a stronger effect than it actually does.

Macroeconomic Policy Implications

Gains through green finance are seen to occur in a short period of time in terms of speed of adjustment, providing a rationale for central banks to support green capital markets. Some of the measures include Recognition of green bonds as eligible collateral; stress testing and capital treatment; climate risk integration into regulation and supervision. Furthermore, the need for regulators to harmonize taxonomy and disclosures arises in the light of the reliability of green labels as an important factor in reaching low carbon through capital. The use of technology has triggered a shift in green finance, which suggests the promotion of technology-enabled reporting and verification from supervisors.

A few indicators similar to those in this graph, including the amount of green finance, issuance of green bonds, carbon intensity of loans, and expenditures on innovations, should be made public, and authorities should encourage the market to monitor whether policy is moving the economy toward the long-run equilibrium. Very short half-life implies that assessments on a yearly or bi-annual basis are sufficient to determine whether the adjustment process is stalling, and that such information can be disseminated between central banks within existing climate finance networks.

The complementarity between green finance and R&D further reinforces the idea that public budget does not have to crowd out private investment. Longer maturities and lower risk premiums can be ensured through the establishment of credit guarantees, first loss tranches, sovereign green bond programmes and/or tax credits for green research. The carbon intensity of projects becomes irrelevant if we take into account the role of finance and innovations, so it must be supplemented with carbon pricing and serve as an encouragement to launch more green projects.

The priority in developing and emerging economies lies in establishing the market infrastructure, i.e. the development of local currency green bond markets and credit enhancement of development banks and institutional quality (determining environmental benefits). As for more developed economies, which already have well-developed markets, the focus will have to be made on the quality and additionality of projects, such as enhanced verifiability of impact, bridging the gap between labelled and real emission reductions and more financing for adaptation and transition sectors. Common taxonomies could help to address fragmentation and direct capital cross-border flows to where it is most needed.

The coordination between financial institutions, governments, and private investors is also crucial in evaluating the impact of the policies on green finance. The ideal policy framework should combine green investment incentives, technological innovation, environmental regulations, and sustainable infrastructure development. The results from the estimated long-run relationship between green finance and sustainable development indicate the possible significance of the consistency of the financial system in providing funds for environmentally friendly economic activities. Moreover, the relatively higher coefficient of green finance in economies with underdeveloped green financial markets proves the possibility of the use of financial interventions to bridge the existing gap in investments. Thus, the key areas of action for the policymakers include institutional development, investment evaluation, and development of

green financial tools. The introduction of environmental performance metrics and cooperation of governmental and private financial organizations could increase the efficiency of capital allocation. In addition, the use of digital financial instruments and sustainability reporting can be helpful in investment transparency and overcoming the problem of information asymmetry.

Three risks arise: firstly, greenwashing lowers investors' trust and misallocates capital; in order to avoid greenwashing, mandatory disclosure and external verification have to be enforced. Secondly, there is the risk of costs arising from guarantees and subsidies, which are contingent liabilities and need to be managed and disclosed. And, thirdly, there is the risk of creating regional imbalances – green capital may turn out as localised as in economies with developed green markets. The logical process of implementation should be: taxonomy and disclosure, broadening eligibility requirements for assets and collaterals, and then targeted incentives, monitored by means of the same index-based approach as in this study.

Link the findings of this research to climate risk management / financial risk management. In recent years, an increasing part of banks' transition risk exposure is coming from green lending activities, and the supervisors regularly require scenario analysis to see whether the transition risk exposure will be positive to the stability of the financial system. Green finance contributes to insuring financial sectors against stranded assets; thus, green finance provides an additional benefit for financial stability, apart from development benefits quantified in this paper.

Conclusion and Future Research Trajectories

In order to analyze the contribution of green finance towards sustainable economic development in this essay, a panel error correction model was employed in this essay on the basis of endogenous growth and ecological economics. There are 4 important lessons from this. First of all, the variables are integrated of order 1 and are cointegrated; thus there is a stable long-run relationship between the variables. Second of all, volume of green finance and green bond issuances are positively and significantly related to the SDI in the long run while green R&D is complementary. Thirdly, the adjustment is very rapid; the half-life is below 1 year. Fourthly, the effect is stronger in regions that have less initial finance in green finance. The value of the long-run coefficient of 0.353 highlights the existence of a positive correlation between the growth of green financing and sustainable development, and the value of the error correction coefficient of -0.545 highlights that about 54.5% of the disequilibrium of the prior year is corrected each year. Moreover, the higher value of the green finance coefficient in the economies having a low level of development of green financial markets (0.422) relative to the value of the green finance coefficient in the economies having a well-developed green financial market (0.307) highlights that the level of maturity of the financial market affects the level of development from the green investment. These results underline the significance of differential financial policies, institutional reforms, and joint investment in renewable energy, technological innovations, and sustainable infrastructure.

Limitations. The illustration has been made on the basis of a simulated panel with the short time span, index of outcome, and one common slope in the long run; the test of cointegration is indicative; the endogeneity of green finance is handled by way of its dynamic structure only. Further research needs to (i) reproduce the exercise by using the actual data set from the World Bank and OECD; (ii) run estimation of pooled mean group and mean group ARDL models to account for different slopes; (iii) use instrumental or GMM approach to measure causality; (iv) analyze threshold effects of institutional quality and digitalization; and (v) study distributional outcomes as per the inclusion perspective. The measurement side can be improved even further in the future. However, a composite index like SDI obscures any trade-offs between income, environmental and social dimensions, and disaggregation may show whether green financing promotes all three dimensions or not. The microdata on the utilization of green bond proceeds can help to identify through which channel of the three the effect takes place, while an event study approach to changes in green bond regulation can produce quasi-experimental proof of the causality. To conclude, the final remark on the practical side. While the elasticities calculated provide the orders of magnitude necessary for the planning – in the case of a thin base economy, the total effect from the increase of the green finance by the proportion is higher, and the proportional increase in the budget will lead to a larger development effect. For the regulator, it is an important result that the adjustment is fast, but the fact that there may be some omitted variables and, therefore, misestimated effect of green finance in the simple model is an appeal to take into account the green financing along with the innovation policy, not separately.

References

Mahmood, S., Sun, H., Iqbal, A., Alhussan, A. A., & El-kenawy, E. S. M. (2024). Green finance, sustainable infrastructure, and green technology innovation: pathways to achieving sustainable development goals in the belt and road initiative. *Environmental Research Communications*, *6*(10), 105036. https://doi.org/10.1088/2515-7620/ad898f

Van Niekerk, A. J. (2024). Economic inclusion: green finance and the SDGs. *Sustainability*, *16*(3), 1128. https://doi.org/10.3390/su16031128

Oanh, T. T. K. (2024). Sustainable development: Driving force from the relationship between finance inclusion, green finance and green growth. *Sustainable Development*, *32*(3), 2811-2829. https://doi.org/10.1002/sd.2808

Guo, L., Mehta, A. M., Asif, M., & Shahzad, M. F. (2026). Sustainable development through green finance: a three-stage hybrid model for environmental planning. *Journal of Environmental Planning and Management*, *69*(10), 3005-3032. https://doi.org/10.1080/09640568.2025.2543799

Sethi, L., Behera, B., & Sethi, N. (2024). Do green finance, green technology innovation, and institutional quality help achieve environmental sustainability? Evidence from the developing economies. *Sustainable Development*, *32*(3), 2709-2723. https://doi.org/10.1002/sd.2811

Behera, B., Behera, P., & Sethi, N. (2024). Decoupling the role of renewable energy, green finance and political stability in achieving the sustainable development goal 13: Empirical insight from emerging economies. *Sustainable Development*, *32*(1), 119-137. https://doi.org/10.1002/sd.2657

Hidayat-ur-Rehman, I., & Hossain, M. N. (2025). The impacts of Fintech adoption, green finance and competitiveness on banks' sustainable performance: digital transformation as moderator. Asia-Pacific Journal of Business Administration, 17(4), 987-1020. https://doi.org/10.1108/APJBA-10-2023-0497

Kumar, B., Kumar, L., Kumar, A., Kumari, R., Tagar, U., & Sassanelli, C. (2024). Green finance in circular economy: a literature review. *Environment, development and sustainability*, *26*(7), 16419-16459. https://doi.org/10.1007/s10668-023-03361-3

Serdarušić, H., Pancić, M., & Zavišić, Ž. (2024). Green finance and Fintech adoption services among Croatian online users: how digital transformation and digital awareness increase banking sustainability. *Economies*, *12*(3), 54. https://doi.org/10.3390/economies12030054

Vardar, G., Aydoğan, B., & Gürel, B. (2025). Investigating the ecological footprint and green finance: evidence from emerging economies. *Journal of Economic and Administrative Sciences*, *41*(5), 1821-1843. https://doi.org/10.1108/JEAS-05-2023-0124

Chin, M. Y., Ong, S. L., Ooi, D. B. Y., & Puah, C. H. (2024). The impact of green finance on environmental degradation in BRI region: M.-Y. Chin et al. *Environment, Development and Sustainability*, *26*(1), 303-318. https://doi.org/10.1007/s10668-022-02709-5

Fu, C., Lu, L., & Pirabi, M. (2024). Advancing green finance: A review of climate change and decarbonization. *Digital Economy and Sustainable Development*, *2*(1), 1. https://doi.org/10.1007/s44265-023-00026-x