Leveraging Public-Private Partnerships for Sustainable Transformation: Empirical Evidence from Emerging Economies

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Abstract

This study takes a closer look at the role of Public-Private Partnerships (PPPs) in supporting sustainable development efforts across emerging economies. At a time when energy transition and environmental protection have become urgent priorities, PPPs are increasingly seen as key instruments for mobilizing private capital, accelerating green innovation, and bridging investment gaps. Drawing on a panel of 18 emerging countries, the research applies a suite of advanced econometric tools including second-generation unit root and cointegration tests, ARDL models, and Granger causality analyses to uncover how PPPs influence environmental outcomes over time. The findings reveal a nuanced story. In the short term, PPPs contribute significantly to reducing environmental degradation, confirming their potential as drivers of positive change. However, the long-term picture is more complex. Without robust regulatory frameworks and a clear alignment with the Sustainable Development Goals (SDGs), these gains may not be sustained echoing the Environmental Kuznets Curve (EKC) pattern. The study shows that it is not just the presence of PPPs that matters, but how they are designed, governed, and monitored. By combining theoretical insights with rigorous empirical evidence, this research offers a fresh perspective on how to make PPPs more effective for sustainability. It not only fills a gap in the literature on the environmental impact of public-private investment in emerging markets but also provides practical recommendations for policymakers seeking to align financial development with long-term ecological resilience.

Keywords: Public-Private Partnerships, Sustainable Finance, Energy Transition, Environmental Outcomes, Emerging Economies

JEL Codes: Q01, Q56, G32, O13

I.INTRODUCTION

In recent years, emerging economies have been navigating a complex transition one that involves not only accelerating economic growth but also doing so in a way that is financially sustainable, energy-efficient, and environmentally responsible. Within this evolving landscape, Public-Private Partnerships (PPPs) have gained renewed attention as flexible and strategic tools capable of mobilizing private investment toward public goals. By facilitating the development of renewable energy infrastructure, promoting innovation, and strengthening institutional capacity, PPPs offer a promising pathway to achieve long-term sustainability targets.

However, their success is far from guaranteed. Ensuring that PPP initiatives contribute meaningfully to environmental and financial goals requires more than investment flows; it demands transparency, accountability, and a coherent integration into national and local development strategies. In particular, the way PPPs are governed, evaluated, and aligned with sustainability standards can determine whether their impacts are short-lived or transformative.

This study seeks to explore how PPPs function within this sustainability framework. Specifically, it examines the extent to which PPPs can serve as effective drivers of energy transition and financial sustainability, while also investigating their relationship with broader environmental performance. Of particular interest is the interaction between PPP-driven financial development and environmental degradation, and how this relationship evolves over time.

The research is guided by a key question: Can PPPs act as catalysts for sustainable transitions in emerging economies, or do their effects depend on deeper structural and policy conditions? Two hypotheses are examined in this context. First, that PPP investments contribute to a reduction in ecological footprint in the short term. Second, that without sustained institutional commitment, this effect may diminish or even reverse over time a dynamic that aligns with the Environmental Kuznets Curve (EKC), which posits a non-linear relationship between development and environmental quality.

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To explore these questions, the study employs a comprehensive empirical strategy, including cross-sectional dependence diagnostics, second-generation unit root and cointegration tests, ARDL modeling, and Granger causality analysis. By combining these methods with a panel dataset covering 18 emerging economies, the research aims to generate evidence that is both methodologically rigorous and relevant for policy and practice.

II. INSIGHTS FROM EXISTING RESEARCH

This conceptual framework illustrates how Public-Private Partnerships (PPPs) serve as levers for promoting energy transition, financial sustainability, and environmental sustainability in emerging economies. The arrows highlight the direction of influence and the specific role each component plays within the system.

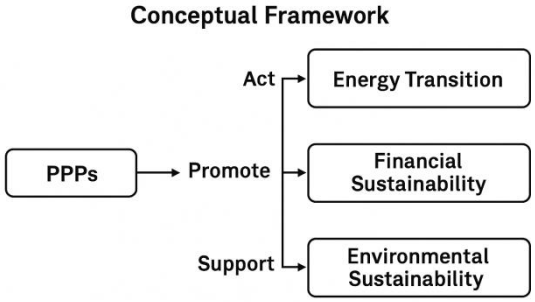

Figure 1. Conceptual Framework: PPPs and Sustainability Goals

This conceptual framework (Figure 1) offers an integrated view of how Public-Private Partnerships (PPPs) operate as key levers to drive sustainability transitions in emerging economies. At the core of the model is the recognition that PPPs do not act in isolation they function within a broader ecosystem of financial systems, energy infrastructures, and environmental governance. The arrows in the framework indicate both direct and indirect pathways of influence, reflecting the multifaceted nature of PPP interventions.

PPPs contribute directly to energy transition by channeling private capital into low-carbon projects such as renewable energy infrastructure, public transportation systems, and energy-efficient buildings. These investments, often supported by state guarantees or incentives, reduce the fiscal burden on governments while accelerating the deployment of green technologies. At the same time, PPPs indirectly enhance financial sustainability by deepening financial markets, diversifying funding sources, and increasing the availability of project-based investment instruments.

From an environmental perspective, PPPs can significantly reduce ecological degradation but only under certain conditions. The framework highlights the importance of institutional quality and regulatory oversight as moderators in this relationship. Without stringent environmental regulations and accountability mechanisms, PPPs risk reinforcing unsustainable practices, particularly if financial development prioritizes profit over environmental impact.

This study makes a unique contribution to the literature by not only visualizing these interconnected pathways but also empirically testing them using robust panel econometric techniques across 18 emerging economies from 1990 to 2021. By incorporating second-generation unit root tests, ARDL estimations, and Granger causality analysis, the research goes beyond simple correlation and delves into the causal mechanisms linking PPPs to financial development, energy consumption, and sustainability outcomes.

Moreover, this framework helps to contextualize the Environmental Kuznets Curve (EKC) within the PPP narrative. It suggests that while PPPs may generate immediate environmental benefits, their long-term effectiveness depends on strategic alignment with sustainability objectives. By conceptualizing PPPs as part of a dynamic system influenced by economic, financial, and institutional factors, this study offers a comprehensive approach to understanding how infrastructure development can be harmonized with climate goals in the Global South.

As emerging economies navigate the dual challenge of sustaining growth while addressing climate and environmental concerns, there is growing momentum around policies that align financial development with energy transition and ecological preservation. In this context, Public-Private Partnerships (PPPs) are increasingly seen not just as financing tools, but as strategic instruments for advancing sustainability goals. By mobilizing private capital, incentivizing innovation, and supporting the deployment of low-carbon infrastructure, PPPs are helping bridge the gap between development needs and environmental commitments.

A growing body of literature highlights the potential of PPPs to accelerate investment in renewable energy and sustainable infrastructure. Studies by Ahmed et al. (2019), Yao and Tang (2021), Wang et al. (2020), Akomea et

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al. (2022), and Kumar et al. (2025) emphasize the ability of PPPs to channel private-sector expertise and funding toward clean energy initiatives. These partnerships have been shown to unlock technological innovation, reduce financing gaps, and improve the implementation of climate-related projects. Complementing these findings, research by Ngo et al. (2024), Nguyen et al. (2023), Sardianou et al. (2021), and Griffith-Jones et al. (2020) underscores how PPPs act as catalysts for broader transitions in green technology and infrastructure. However, the effectiveness of these mechanisms depends heavily on the institutional context. As Adebayo et al. (2023) argue, strong regulatory frameworks are crucial to avoid inefficiencies and ensure long-term sustainability gains.

The literature on sustainable finance offers further insight into the dynamics between investment mechanisms and environmental outcomes. Authors such as Lv and Li (2021), Crifo et al. (2020), and again Adebayo et al. (2023) describe a dual pattern: while sustainable finance often deployed through PPPs has a positive impact on emissions and resource use in the short term, this effect may taper off or even reverse if the underlying governance and regulatory environment is weak. This non-linear relationship aligns with the Environmental Kuznets Curve (EKC), which posits that environmental degradation initially worsens with economic development, before improving once income and institutional capacity reach a certain threshold (Panayotou, 1993; Shahbaz and Sinha, 2019; Dasgupta et al., 2023).

Despite these valuable contributions, key gaps remain. The long-term environmental impact of PPPs remains underexplored, particularly in the diverse institutional settings of emerging economies. Much of the existing literature focuses on short-term efficiency or financial viability, often neglecting the ecological consequences beyond the project life cycle. Moreover, few studies have systematically analyzed the conditions under which PPPs can shift from environmentally beneficial to potentially harmful especially in cases where financial development is not explicitly tied to sustainability objectives. There is also a noticeable lack of empirical research employing rigorous, multi-dimensional methodologies to examine the causal pathways between PPPs, sustainable finance, and environmental performance (Tamazian et al., 2009; Jalil and Feridun, 2011; Salahuddin and Alam, 2015).

This study contributes to filling these gaps by proposing a conceptual and empirical framework that brings these elements together. As illustrated in Figure 1, the research explores how PPPs influence sustainability outcomes through both direct and indirect channels such as financial development, energy transition, and sustainable spending while also considering the role of institutional quality and regulatory stability in shaping long-term environmental effects. By employing second-generation panel econometric techniques across 18 emerging economies, this study offers new empirical evidence on how PPPs can be better leveraged to align infrastructure development with global climate and sustainability objectives.

III. METHODOLOGY AND DATA

Our empirical investigation focuses on a carefully selected panel of 18 emerging economies, chosen for their strategic importance in the global transition toward sustainable development. This group includes countries from the BRICS and Asia-Pacific regions: South Africa, Saudi Arabia, India, China, Russia, Brazil, Argentina, Colombia, Malaysia, Mexico, Peru, the Philippines, Poland, Thailand, Turkey, South Korea, and Chile. These nations were selected based on their economic influence, dynamic energy landscapes, and increasing reliance on Public-Private Partnerships (PPPs) as instruments for achieving development goals. The dataset spans the period from 1990 to 2021, and data were sourced primarily from the World Bank and the International Monetary Fund (IMF), ensuring consistency and international comparability.

To examine the intricate relationships among sustainability, financial systems, and PPPs, we employed a comprehensive set of variables. Environmental sustainability (SD) is measured using adjusted net savings as a percentage of GDP, a well-established indicator that accounts for investment in human capital, depletion of natural resources, and environmental damage. PPP investments focus specifically on the energy sector, reflecting the sector's critical role in enabling low-carbon transitions. The ecological footprint (EF) represents a multidimensional measure that aggregates the pressure exerted by human activity across six key categories: carbon emissions, cropland, grazing land, fishing grounds, forest land, and built-up areas. Energy consumption (EC) provides a macro-level view of national energy demand. Financial development (FD) is captured by domestic credit to the private sector as a share of GDP, a commonly used proxy for financial depth. GDP per capita is included as a measure of economic performance and living standards. In addition, a new composite indicator termed "PPP-SD" was developed to assess the degree of alignment between PPP investments and sustainable development objectives.

To understand how these variables interact over time and across countries, we developed two empirical models, drawing inspiration from the methodology of Hunjra et al. (2023). The first model examines the determinants of ecological pressure, with a specific focus on how PPPs, financial development, and macroeconomic factors contribute to changes in the ecological footprint. The second model incorporates the moderating role of PPP-SD to explore how sustainable PPP initiatives influence broader outcomes in environmental sustainability.

Model 1: $$\boldsymbol{EE_{i,t} = \delta_i + \alpha_1 EE_{i,t-1} + \alpha_2 PPP_{i,t} + \alpha_3 SD_{i,t} + \alpha_4 FD_{i,t} + \alpha_5 CE_{i,t} + \alpha_6 GDP_{i,t} + \varepsilon_{it}}$$

Model 2 (including the moderating effect of PPP-SD):

$$\boldsymbol{SD_{i,t} = \delta_i + \alpha_1 SD_{i,t-1} + \alpha_2 PPP_{i,t} + \alpha_3 EE_{i,t} + \alpha_4 FD_{i,t} + \alpha_5 CE_{i,t} + \alpha_6 GDP_{i,t} + \alpha_7 (PPP - SD)_{i,t} + \varepsilon_{it}}$$

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Our methodological approach is organized into four key phases. First, we perform cross-sectional dependence (CD) tests to identify the presence of interdependencies among the countries in the panel, which could result from global shocks or regional spillovers. Recognizing such dependencies is essential for the proper specification of panel models. Second, we use second-generation unit root tests specifically, the Cross-sectionally Augmented Dickey-Fuller (CADF) and the Cross-sectionally Imposed Panel Unit Root (CIPS) tests proposed by Pesaran to assess the stationarity of each variable. These tests are particularly well-suited for panel datasets where cross-sectional correlation is expected.

Third, we conduct panel cointegration tests based on Pedroni's methodology to verify whether long-run equilibrium relationships exist among the variables. Where cointegration is confirmed, we apply the Autoregressive Distributed Lag (ARDL) modeling approach to estimate both short-term and long-term relationships. This technique allows for flexibility in handling variables with different levels of integration and offers reliable estimates even in small sample panels.

Finally, we implement Pairwise Granger causality tests to examine the directionality of relationships among key variables. This step provides valuable insights into which variables act as drivers and which respond to changes, supporting evidence-based policy recommendations.

All empirical analyses were conducted using STATA software, a platform known for its robustness and flexibility in handling panel econometric models. The methodological rigor adopted in this study ensures that the conclusions drawn are not only statistically sound but also relevant for designing effective and sustainable public-private collaboration frameworks in emerging economies.

IV. EMPIRICAL FINDINGS AND INTERPRETATIONS

Before proceeding with the main econometric estimations, several diagnostic tests were carried out to ensure that the empirical framework was both robust and well-specified. These initial checks serve to validate the methodological choices and to preclude risks of misspecification or spurious relationships.

As presented in Annex Table 1, the results from the Pesaran LM and Pesaran CD tests provide compelling evidence of cross-sectional dependence among the panel countries. This means that external shocks or policy changes in one country tend to spill over into others, a feature that is not uncommon in increasingly interconnected global economies. Specifically, all core variables used in the study namely ecological footprint (LNEF), financial development (LNFD), GDP per capita (LNGDP), energy consumption (LNEC), sustainable development spending (LNSD), green finance (LNGF), and PPP investment in sustainable development (LNPPP-SD) exhibit statistically significant results at the 1% level. These outcomes validate the use of second-generation panel econometric techniques that are designed to account for such interdependencies, making the model selection both theoretically and statistically justified.

Following the cross-sectional analysis, unit root tests were conducted to evaluate the stationarity properties of the dataset. The results, summarized in Annex Table II, stem from both ADF-Fisher and CIPS tests. Most variables are found to be non-stationary at level but become stationary after first differencing, indicating that they are integrated of order one, or I(1). Interestingly, GDP (LNGDP) and green finance (LNGF) appear stationary in levels according to both test frameworks, classifying them as I(0). This mixture of integration orders makes the ARDL-Pooled Mean Group (PMG) methodology an appropriate choice for estimating the models, as it accommodates combinations of I(0) and I(1) variables as long as none of them are I(2). These unit root diagnostics thus confirm the validity of the subsequent estimations and provide a strong foundation for reliable inference.

Table 1 consolidates the outcomes from the Pedroni cointegration tests and the optimal lag selection procedures based on the Akaike Information Criterion (AIC). For Model 1, which examines the determinants of the ecological footprint, the cointegration test involving variables such as LNEF, LNFD, LNSD, LNEC, LNGF, and LNGDP yields a Pedroni test statistic of –3.5259 with a p-value of 0.0002. This result strongly suggests the presence of a long-run equilibrium relationship among these variables. In Model 2, which expands the analysis to include PPP-aligned sustainable investments (LNPPP-SD), the Pedroni test produces an even more significant statistic of –4.2270 (p-value=0.0000), reinforcing the presence of stable, long-term associations among the selected indicators.

Simultaneously, the selection of the optimal lag length was guided by the minimization of the AIC. For both models, the ARDL(1,1,1,1,1) configuration emerged as the most suitable. This lag structure ensures that the models remain parsimonious capturing key dynamics without overfitting while also preserving the interpretability of both short-term fluctuations and long-term trends.

Taken together, these preliminary findings establish a strong empirical basis for the ARDL

estimations presented in the next section. The rigorous testing strategy enhances confidence in the robustness of the results and ensures that the derived insights will be grounded in statistically valid and economically meaningful relationships.

TABLE I: PEDRONI COINTEGRATION AND LAG SELECTION RESULTS

Model	Variables	Pedroni	Lag	AIC*	ARDL

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	Involved	Stat (p-val)			Spec.
1	LNEF, LNFD, LNSD, LNEC, LNGF, LNGDP	-3.5259 (0.0002)***	1	-3.8194	ARDL(1,1,1,1,1)
2	LNSD, LNEF, LNFD, LNGDP, LNGF, LNPPP-SD, LNEC	-4.2270 (0.0000)***	1	-3.8267	ARDL(1,1,1,1,1)

(***) significant at 1%

Table II presents the results of the ARDL estimation for two models. Model 1 explores the determinants of the ecological footprint (LNEF), while Model 2 examines the drivers of environmental sustainability (LNSD). The findings reveal nuanced short-term and long-term dynamics that help address the core research question concerning the catalytic role of Public-Private Partnerships (PPPs) and financial development in sustainable transitions.

TABLE II: ARDL ESTIMATION RESULTS

Model	Variable	Short-Term Coefficient	Long-Term Coefficient
Model 1 (LNEF)	LNFD	-0.0055**	0.319**
Model 1 (LNEF)	LNGDP	-0.145**	-0.127**
Model 1 (LNEF)	LNEC	0.396**	0.021
Model 1 (LNEF)	LNSD	-0.001	0.001
Model 1 (LNEF)	LNGF	-0.002**	0.029**
Model 2 (LNSD)	LNPPP-SD	0.419***	0.259***
Model 2 (LNSD)	LNEF	-1.408	-2.412**
Model 2 (LNSD)	LNFD	1.678	0.860
Model 2 (LNSD)	LNGDP	5.423**	0.166*
Model 2 (LNSD)	LNGF	-1.094	-0.834***
Model 2 (LNSD)	LNEC	0.497	-2.674

(***, **, * SIGNIFICANT AT 1%, 5%, 10%)

Before delving into the results of the ARDL estimations, it is essential to recall that two distinct models were employed to explore the dynamics between financial development, ecological degradation, and environmental sustainability. Model 1 focuses on the ecological footprint (LNEF) as the dependent variable, while Model 2 uses sustainable development spending (LNSD) to capture the broader dimension of sustainability.

In Model 1, the short-term coefficient for financial development (LNFD) is negative and statistically significant at the 5% level (-0.0055), suggesting that an expansion in financial services initially contributes to lowering the ecological footprint. This result may be attributed to increased access to finance supporting investments in cleaner technologies, more efficient production processes, or greener infrastructure. However, the long-term coefficient for LNFD flips sign and becomes significantly positive (0.319), aligning with the Environmental Kuznets Curve (EKC) hypothesis. This shift implies that, in the absence of effective environmental regulations and sustainable financial allocation mechanisms, the continued growth of financial systems might eventually result in higher resource consumption and environmental pressure. Financial development, therefore, acts as a double-edged sword: beneficial in early stages but potentially detrimental if left unchecked.

The impact of economic growth (LNGDP) also presents a nuanced story. Both the short- and long-term coefficients are negative and significant (-0.145 and -0.127, respectively), indicating that under certain conditions, rising GDP per capita can contribute to environmental improvement. This supports the notion of green growth, particularly in contexts where economic expansion is closely tied to investments in low-carbon technologies and environmental regulations.

Energy consumption (LNEC) in Model 1 shows a statistically significant and positive short-term coefficient (0.396), underscoring its role in exacerbating environmental degradation, especially in fossil fuel-dependent economies. However, the long-term coefficient (0.021) loses statistical significance, which could reflect a gradual shift towards cleaner energy systems or improved energy efficiency practices.

Sustainable development spending (LNSD) exhibits no significant effect in either the short or long run, pointing to a disconnect between expenditure and tangible environmental outcomes. This raises questions about the effectiveness of current spending practices and suggests a need for better governance, impact assessment, and alignment with measurable environmental goals.

Green finance (LNGF) adds another layer of complexity. In the short term, its coefficient is negative and significant (-0.002), indicating that green financial instruments, when initially deployed, help reduce ecological damage. However, in the long term, the effect turns positive and significant (0.029), suggesting that without rigorous

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monitoring or performance-linked mechanisms, green finance might lose effectiveness or be diverted toward less impactful projects.

Model 2 provides a complementary perspective by examining how these variables affect sustainable development (LNSD) directly. PPP investments in sustainable development (LNPPP-SD) emerge as a particularly influential variable, with highly significant positive coefficients in both the short (0.419) and long term (0.259). This finding underscores the transformative potential of well-structured PPPs in advancing sustainability objectives and confirms the central hypothesis of this study.

Interestingly, the ecological footprint (LNEF) exerts a negative and significant influence on sustainable development in the long term (-2.412), reinforcing the idea that environmental degradation ultimately undermines sustainability outcomes. In contrast, financial development (LNFD) shows a positive but statistically insignificant effect, highlighting the context-specific nature of its contribution and the need for stronger institutional frameworks to guide its environmental role.

Economic growth (LNGDP) continues to play a supportive role, with a significant short-term coefficient (5.423) and a modest but significant long-term impact (0.166). These results suggest that economic activity, when oriented towards sustainable goals, can be a driver of long-term progress.

Green finance (LNGF), however, shows a troubling trend. Its long-term effect is significantly negative (-0.834), implying that the misalignment or inefficiency of green financial flows may harm rather than support sustainable development. This could be due to greenwashing, poor project selection, or lack of transparency in fund allocation.

Finally, energy consumption (LNEC) reveals a strongly negative but statistically insignificant long-term coefficient (-2.674), suggesting that high energy demand continues to threaten sustainability, particularly when driven by non-renewable sources.

Taken together, the results from both ARDL models offer a nuanced but coherent picture. While financial development and PPPs can act as catalysts for short-term improvements in environmental and sustainability metrics, their long-term efficacy hinges on governance, regulatory coherence, and the strategic targeting of resources. These findings underscore the need for integrated policy frameworks that promote not only financial expansion and investment but also environmental accountability and performance-based sustainability outcomes.

TABLE III: PAIRWISE GRANGER CAUSALITY TEST RESULTS

Cause \ Effect	LNEF	LNFD	LNGDP	LNEC	LNGF	LNSD
LNEF	—	1.303	2.682*	1.365	3.963**	1.415
LNFD	0.293	—	1.071	5.318***	0.469	4.426**
LNGDP	0.456	49.285***	—	2.510*	3.449**	0.437
LNEC	0.186	6.051***	2.634*	—	0.168	7.155***
LNGF	0.568	0.284	2.270	1.467	—	0.393
LNSD	0.636	3.749**	4.302**	0.366	2.789*	—

(***, **, * SIGNIFICANT AT 1%, 5%, 10%)

The Granger causality test results in Table 3 provide a detailed view of how variables relevant to environmental and financial sustainability interact dynamically over time in the studied emerging economies. This analysis sheds light on directional relationships, helping to uncover which variables serve as leading indicators and which ones respond to systemic changes.

One of the most statistically robust relationships observed is the influence of economic growth on financial development. The significant causality from GDP (LNGDP) to financial development (LNFD) at the 1% level highlights that when an economy experiences sustained growth, it typically enjoys improved capital availability, expanded financial markets, and more robust investment infrastructure. This underscores the role of macroeconomic stability as a prerequisite for building a resilient financial system, particularly in emerging markets aiming to attract both domestic and foreign investment.

Financial development (LNFD) in turn significantly Granger-causes energy consumption (LNEC) and sustainable development spending (LNSD), suggesting that deeper financial systems facilitate access to capital for both conventional energy projects and sustainability-oriented initiatives. While this expansion of financial flows can be beneficial, it also carries potential risks. Without appropriate environmental safeguards and investment criteria,

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increased financial activity may inadvertently fund environmentally harmful industries, thereby worsening ecological outcomes.

Energy consumption (LNEC) is shown to Granger-cause sustainable development (LNSD) at the 1% level, indicating the centrality of energy management in sustainability agendas. For economies still heavily reliant on fossil fuels, this relationship points to the importance of transitioning to renewable sources and implementing energy efficiency measures. Otherwise, rising energy use could continue to hinder environmental objectives.

Sustainable development (LNSD) itself Granger-causes both financial development and GDP at the 5% significance level, revealing a feedback loop in which sustainability is not merely a product of economic growth but also a catalyst for it. When sustainability goals are embedded in policy through initiatives such as public-private partnerships (PPPs), they contribute to broader economic and financial progress, promoting innovation, employment, and resilience across sectors.

The role of green finance (LNGF) appears more subdued in the causality matrix. Although it is influenced by GDP growth, it does not significantly Granger-cause other variables, including ecological footprint or sustainability spending. This suggests that green finance is still underutilized as a policy tool in many emerging markets. Institutional limitations, lack of clear performance benchmarks, and insufficient regulatory support may all contribute to its limited effectiveness. To transform green finance into a more proactive force, targeted reforms are necessary to enhance transparency, improve impact tracking, and align financing mechanisms with long-term sustainability goals.

Additional causality flows from GDP to energy consumption and green finance further confirm that economic expansion increases energy demands and spurs financial innovation. Yet, the absence of causality in the reverse direction from green finance to economic performance or energy usage raises concerns about whether green financial instruments are being strategically directed toward transformative projects that could shift the structural trajectory of these economies.

The causality evidence thus supports the study's core hypothesis: PPPs and financial development can positively contribute to sustainable transitions, but their long-term effectiveness depends heavily on institutional design and regulatory coherence. The presence of short-term improvements offers a foundation for optimism; however, achieving long-lasting change requires embedded accountability, well-structured financial tools, and a strong alignment with climate and development priorities.

Policy implications from this analysis are clear. PPP contracts should include enforceable sustainability metrics and regular performance audits. Financial tools such as green bonds and blended finance schemes should be deployed within regulatory environments that are consistent, transparent, and investor-friendly. Furthermore, international cooperation remains indispensable, not only for financial support but also for transferring technology and institutional expertise.

Looking forward, future research should explore how these causal relationships vary across sectors and regions. Comparative evaluations between emerging and advanced economies can provide guidance on scalable practices and innovations. These insights collectively highlight the importance of interdisciplinary coordination between financial, energy, and environmental policymakers to ensure that PPPs and green finance become lasting engines of sustainable development.

V.CONCLUSION

This research set out to examine the role of Public-Private Partnerships (PPPs) as catalysts for accelerating energy transition, promoting financial sustainability, and enhancing environmental outcomes in emerging economies. Relying on robust empirical methods applied to a panel of 18 countries, the study provides compelling evidence that PPPs exert a measurable and positive influence on ecological performance particularly in the short term by facilitating infrastructure investment, mobilizing private capital, and fostering green innovation.

However, the analysis also highlights that these initial benefits are not automatically sustained over time. Long-term results suggest a potential reversal of short-term gains, consistent with the Environmental Kuznets Curve (EKC) hypothesis. This indicates that economic and financial progress may, in the absence of effective regulatory safeguards, reignite environmental degradation. Such non-linear dynamics underscore the critical importance of embedding sustainability criteria within the institutional and financial frameworks that guide PPP implementation.

In this context, aligning PPP objectives with the Sustainable Development Goals (SDGs) becomes a strategic necessity. Integrating environmental sustainability into project governance, financial structuring, and monitoring mechanisms enhances the resilience and long-term impact of PPPs in emerging markets. When appropriately designed and managed, PPPs can move beyond short-term efficiency gains and serve as foundational elements of inclusive, low-carbon growth strategies.

From a theoretical perspective, this study contributes to the sustainability literature by extending the EKC framework into the field of public-private investment. It reveals the dual nature of PPPs as both enablers and potential stressors of environmental sustainability depending on how they are framed, financed, and governed. Empirically, the study bridges a gap by providing panel-based evidence on the temporal effects of PPPs, incorporating macroeconomic indicators and sectoral investment data.

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The findings carry important implications for policymakers and development practitioners. Effective PPP governance must go beyond financial engineering. It requires strategic foresight, rigorous environmental assessment, and the integration of sustainability performance metrics into decision-making processes. By anchoring PPPs in transparent, accountable, and goal-oriented frameworks, emerging economies can better position these partnerships as reliable pillars of their climate and development agendas. Ultimately, this study affirms that when properly aligned with sustainability principles, PPPs can function not only as tools for infrastructure financing but also as proactive agents of transformative, ecologically responsible development.

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ANNEX

TABLE 1 CROSS-SECTIONAL DEPENDENCE (CD) TEST RESULTS

Variable	LM (PESARAN)	CD (PESARAN)
LNEF	174.93 (0.000)***	49.19 (0.000)***
LNFD	71.95 (0.000)***	26.91 (0.000)***
LNGDP	219.21 (0.000)***	61.17 (0.000)***
LNEC	90.83 (0.000)***	23.61 (0.000)***
LNSD	32.19 (0.000)***	8.96 (0.000)***

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LNGF	6.91 (0.000)***	6.91 (0.000)***
LNPPP-SD	17.53 (0.000)***	9.91 (0.000)***

(*** Significant at 1%)

TABLE 2UNIT ROOT TEST RESULTS

Variable	ADF-Fisher (Level)	ADF-Fisher (1st Diff.)	CIPS (Level)	CIPS (1st Diff.)	Order of Integration
LNEF	10.79	102.61***	5.06	-8.23***	I(1)
LNFD	47.29	166.10***	-1.05	-9.90***	I(1)
LNGDP	119.64***	116.19***	-4.22***	-6.57***	I(0)
LNEC	26.25	118.78***	2.64	-7.26***	I(1)
LNSD	44.95*	159.87***	-1.62	-9.63***	I(1)
LNGF	89.26***	207.70***	-6.03***	-13.33***	I(0)

(***, **, * significant at 1%, 5%, 10%)

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