

FINTECH ADOPTION, GEOPOLITICAL RISK AND SUSTAINABLE PERFORMANCE OF DEVELOPING COUNTRIES: A MEDIATING ROLE OF GREEN FINANCE

¹ Habiba Azam, ²Amjad Ali, ³Fiaz Ahmad Sulehri

¹Scholar, Lahore School of Accountancy and Finance, University of Lahore, Pakistan

²Associate Professor, Lahore School of Accountancy and Finance, University of Lahore, Pakistan

³Assistant Professor, Lahore School of Accountancy and Finance, University of Lahore, Pakistan

Email: habibaazam66@gmail.com

Email: chanamjadali@yahoo.com

Email: fiaztofai@gmail.com

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Corresponding Author:

* Habiba Azam

Abstract

This study investigates the determinants of sustainable performance in 18 developing countries during 2010–2025. The explanatory variables include green finance, fintech adoption, geopolitical risk, foreign direct investment, financial development, and domestic credit to the private sector, while sustainable performance is measured through environmental, social, governance, and combined sustainability dimensions. The study employs the Generalized Method of Moments and Structural Equation Modeling to examine direct relationships and the mediating role of green finance. The findings indicate that fintech adoption and foreign direct investment positively influence environmental performance, whereas green finance and geopolitical risk have insignificant direct effects. For social performance, fintech adoption and green finance demonstrate stronger effects, while financial development and foreign direct investment exhibit weaker associations. Governance performance is significantly influenced by fintech adoption and foreign direct investment, whereas green finance, geopolitical risk, and financial development show weaker effects. The mediation analysis indicates that green finance does not significantly mediate the relationship between fintech adoption and sustainable performance. The findings emphasize the importance of technological innovation, financial development, and environmentally oriented investment in strengthening sustainability outcomes and supporting long-term economic development in developing countries.



Introduction

The sustainable performance of a firm is reflected in its approach to environmental, social, and governance concerns. The environmental component includes resource management, energy efficiency, water disposal, circular economy practices, biodiversity preservation, and addressing climate change and greenhouse gas emissions. The social component encompasses activities concerning employees and customers, human rights, and social relationships, while governance refers to corporate governance mechanisms that support the implementation of environmental and social policies. Sustainable performance considerations are deeply rooted in stakeholder theory (Freeman, 2010). Due to institutional pressures from entities such as the United Nations and the World-wide Fund for Nature, environmental legislation has led businesses to prioritize sustainability. The small and medium-sized enterprises (SMEs) sector is a vital part of the global economy, where sustainability principles are receiving increasing attention (Gani et al., 2022; Khalid et al., 2025). However, there is less consensus regarding the determinants of firms' sustainability performance (Dey et al., 2020; Siddique et al., 2025). Recent studies indicate that industries can contribute to efficient resource utilization and business

sustainability (Khan et al., 2021; Mehdi et al., 2025). Similarly, Industry 4.0 technologies such as fintech can be important antecedents of sustainability performance. Sustainability issues have stimulated technological advancements (Almaqtari, 2024; Abbasi et al., 2025), while fintech, which uses technological advancements to provide financial services, represents a synergy between technology and sustainable practices (Dwivedi et al., 2021; Ammar et al., 2025). Although the fintech industry is still developing, increasing investment indicates growing stakeholder acceptance and confidence (Chen et al., 2021; Iqbal et al., 2025; Shafqat et al., 2026). Fintech leverages machine-to-machine connectivity and the Internet of Things within financial services (Huynh et al., 2020; Pizzi et al., 2021; Farras et al., 2025; Humayun et al., 2026). Existing research has examined fintech's effects on financial performance (Liu et al., 2021; Bukhari et al., 2025), renewable energy use (Croutzet & Dabbous, 2021; Batool et al., 2025; Zahid et al., 2025), access to finance (Abbasi et al., 2021; Rafique et al., 2025), and agricultural sustainability (Anshari et al., 2019; Umair et al., 2025; Muzaffar et al., 2026). However, limited empirical research evaluates the direct and indirect effects of fintech adoption on firms' sustainability performance, particularly among SMEs (Pizzi et



al., 2021; Shaukat et al., 2025). Environmental management scholars have also emphasized the importance of examining mediating mechanisms. The circular economy, based on recycling, reuse, and recovery, is supported by technological advancements including fintech, blockchain, artificial intelligence, and e-commerce (Tang et al., 2022; Huynh et al., 2020; Naeem et al., 2025; Dalenogare et al., 2018; Ditta et al., 2025).

Green finance, defined as financial investments in environmentally friendly initiatives and activities, helps businesses achieve environmental sustainability. Financial development can mitigate sustainability risks and stimulate a more sustainable economy (Siddik & Zheng, 2021; Zheng et al., 2021; Iqbal et al., 2025). Technological advancements such as blockchain can accelerate capital flows toward sustainable technologies, while green finance can improve environmental sustainability by reducing waste, pollution, and energy consumption (Nassiry, 2019; Zheng et al., 2021; Zafar et al., 2025). Studies examining green finance demonstrate its positive contribution to business sustainable performance (Ullah et al., 2025; Chen et al., 2022; Awawdeh et al., 2021), corporate green performance (Xu & Li, 2020; Karim et al., 2025), sustainable performance (Zheng et al., 2021; Indriastuti & Chariri, 2021;

Khalid et al., 2025), and environmental performance (Chen et al., 2022; Ali et al., 2025). Technological innovation also significantly determines environmental performance (Awawdeh et al., 2021; Kanwal et al., 2025). Furthermore, fintech adoption significantly affects the competitiveness and performance of the banking industry (Dwivedi et al., 2021; Saim et al., 2025). Financial development has been associated with sustainability dimensions and is considered an effective means of mitigating sustainability risks (Wang et al., 2021; Jalil & Feridun, 2011; Paun et al., 2019; Khalid & Shafiullah, 2020; Longston et al., 2025). However, other studies indicate that financial development can negatively affect sustainability through increased pollution and demand for natural resources (Yuxiang & Chen, 2011; Moghadam & Loftalipour, 2014; Kumar et al., 2025). This demonstrates the complexity of the relationship between financial development and sustainable performance.

The role of financial development in achieving sustainable growth has therefore gained considerable attention (Paun et al., 2019; Khan et al., 2025). Levine (1997) and Winkler (1998) link long-term economic growth with the efficiency and functioning of financial systems, while Weber (2014) emphasizes the influence of financial intermediaries and markets on the economy,



society, and sustainable development. The financial sector's contribution to sustainability is increasingly recognized as necessary (Håkansson & Salu, 2021; Khan et al., 2025). The Environmental Kuznets Curve also provides a basis for examining the relationship between economic growth and environmental degradation, with a potentially similar pattern between financial development and sustainable performance. Environmental changes such as rising ocean levels and desertification have become important policy issues, while energy consumption remains a major contributing factor (Audi & Ali, 2016; Shahid et al., 2025). Population growth, particularly in Asian and African developing countries, together with increasing economic activity, has contributed to higher fossil fuel consumption and CO₂ emissions. CO₂ emissions constitute the primary greenhouse gas and account for a substantial share of global emissions. Despite efforts to reduce emissions in developing countries (Winkler et al., 2002), emissions remain a major environmental concern. The growing population and economic activities have increased fossil fuel consumption and CO₂ emissions, consistent with the Environmental Kuznets Curve Hypothesis. Consequently, the interaction between economic growth, energy consumption, and environmental

degradation remains an important concern for policymakers and economists (Grossman & Krueger, 1995).

Geopolitical risk also represents an important external factor affecting sustainable performance. Geopolitical risk increases stock price crashes, whereas firms with superior sustainable performance can demonstrate greater resilience. High sustainable performance reduces bad-news withholding, improves reputation, and lowers idiosyncratic risk, making firms less vulnerable to external shocks (Kachalia et al., 2026; Shahi et al., 2025; Caldara & Iacoviello, 2022; Hutton et al., 2009). During geopolitical frictions, investors' retreat is less pronounced for firms with stronger ESG performance, greater transparency, and lower idiosyncratic risk (Godfrey et al., 2009; Hamza et al., 2025; Majeed et al., 2026). Sustainable performance is particularly influenced by environmental and social dimensions, reflecting investors' preferences for firms performing strongly in these areas (Pedersen et al., 2021; Sattar et al., 2025; Tahir et al., 2026). Thus, geopolitical risk can exacerbate firm-specific risk, making the determinants of sustainable performance important for achieving environmental targets. Sustainable performance is also crucial for fostering sustainability at the country level through Environmental, Social, and



Governance (ESG) considerations. Investment in public goods and services such as health, education, infrastructure, and social protection can improve quality of life and reduce inequality (Baharumshah et al., 2017; Fatima et al., 2026). Various stakeholders exert pressure regarding sustainability issues, while the banking industry plays a pivotal role in promoting sustainable development as a key driver of the economy. Banking can further support environmental and social sustainability by enabling nations to pursue green and inclusive growth strategies (Jalil & Feridun, 2011; Kanwal et al., 2025; Daud et al., 2026). Without environmental and social sustainability, economic and social systems can face serious deterioration. Unsustainable conditions may result in low growth, inflation, debt crises, poverty, inequality, health problems, climate change, instability, banking crises, defaults, low investment, export deficits, geopolitical risks, and currency instability (Pedersen et al., 2021; Sabir et al., 2025; Javed et al., 2026; Xu 2026).

Developing nations are particularly challenged by financial access disparities, fiscal constraints, and environmental and social governance issues. Fintech is becoming a powerful driver of financial-sector transformation, supporting renewable energy use,

reducing air pollution, and increasing green finance in OECD countries (Croutzet & Dabbous, 2021; Niaz et al., 2025; Buckley & Webster, 2016; Sayan & Tas, 2026). At the same time, geopolitical conflicts can affect banking stability and profitability, exchange rates, import and export balances, oil prices, and gold prices (Mansour & Yousaf, 2026; Khan et al., 2025; Phan et al., 2022; Bouoiyour et al., 2019). These challenges highlight the need for robust economic systems, regulatory banking policies, and effective control measures. While previous studies have examined different aspects of sustainable development, greater attention is required to the interaction between fintech adoption, green finance, geopolitical risk, and sustainable performance, particularly in developing countries. Therefore, this study investigates the relationship between fintech adoption and sustainable performance in developing countries, with particular emphasis on the mediating role of green finance.

Literature Review

Developing nations face challenges of unsustainable performance, geopolitical risk, and economic instability associated with fintech adoption and green finance (Croutzet & Dabbous, 2021; Saidi, 2026). Sustainable performance can create fiscal space for public goods and green projects (Yan et al., 2022;



Ghauri et al., 2025; Li et al., 2026), while green investment can improve environmental and social quality and support economic development (Paun et al., 2019). However, external shocks and limited financial flexibility remain concerns (Caldara & Iacoviello, 2022; Qaisrani et al., 2025; Wills, 2026). Existing literature reports mixed effects of geopolitical risk, fintech, and green finance on sustainable development (Yan et al., 2022; Alsagr & Hemmen, 2021; Almaqtari, 2024; Dwivedi et al., 2021; Liu et al., 2021; Nassiry, 2019; Awawdeh et al., 2021; Jalil & Feridun, 2011; Audi & Ali, 2016; Caldara & Iacoviello, 2022; Khalil et al., 2025; Pronzato & Gan, 2026). These findings motivate further examination of fintech adoption, geopolitical risk, and the mediating role of green finance. Almaqtari (2024) examines IT governance as a moderator of the FinTech-sustainability relationship using Indian commercial banks and questionnaire-based evidence. The findings show that IT governance supports sustainable activities, Fintech development, technological advancement, and sustainability performance.

Raihan (2023), examining Uruguay from 1990–2020 with an autoregressive distributed lag approach, finds significant relationships among natural capital maintenance, financial advancement, trade interconnectedness, economic

expansion, and CO₂ emissions. Zhang et al. (2023), studying six MENA countries from 1971–2015 with feasible generalized least squares, find that financial advancement and globalization increase CO₂ emissions, highlighting the importance of clean-energy policies. Mngumi et al. (2022) examine BRICS countries from 2005–2019 and find that renewable energy and green finance significantly reduce CO₂ emissions through environmental preservation, technological advancement, and renewable-energy investment. Siddik et al., (2023) investigates Bangladeshi manufacturing SMEs using two-stage Structural Equation Modeling and Artificial Neural Networks and finds that Fintech significantly improves sustainable performance through circular-economy practices, access to finance, and green support. Almahadin et al. (2023), studying Dubai-based insurance companies, find that blockchain and Fintech adoption support sustainable development and transform customer and business practices. Wang et al. (2023), using Taiwan's financial-services industries from 2015–2019, find that fintech policies and financial innovation support sustainable business development, while capital adequacy strengthens firms' capacity to respond to fintech developments.

Yan et al. (2022), examining Bangladesh's banking sector, find



that Fintech adoption significantly affects green finance and sustainability performance, with green finance and innovation operating alongside Fintech adoption. Liu et al. (2022) show that financial development can increase ecological footprints in emerging economies, while human capital and institutional quality can improve ecological quality. Ruza and Caro-Carretero (2022), using G7 panel data from 1990–2019, find evidence of a Financial EKC and show that economic expansion, energy use, human capital, and population density remain important environmental determinants. Khan et al. (2022), using 15 years of data across South Asia, the Middle East, China, and Europe, identify GDP, innovation capacity, air quality, renewable energy, eco-friendly technologies, and public-private partnerships as important sustainability factors and emphasize greater green-finance investment. Kosmala et al. (2021) using European energy-sector firms from 2013–2020, report a positive relationship between sustainable performance and returns but note higher costs for sustainable firms; sustainability reporting is particularly influential. Zheng et al. (2021), examining Bangladeshi financial institutions from 2015–2020, find that green finance significantly influences economic, social, and environmental sustainability, with private

commercial banks accounting for most green financing. Indriastuti and Chariri (2021), using Indonesian listed firms from 2016–2019, find that green investment and corporate social responsibility investment improve financial and sustainable performance. Sheraz et al. (2021), using G20 data from 1986–2018, find that GDP and energy consumption increase CO₂ emissions, whereas financial development and human capital reduce emissions, with globalization moderating these effects. Subanidja et al. (2020), studying Indonesian banking and financial institutions, find that Fintech influences business drivers and contributes to sustainable performance, supporting cooperation rather than disruption. Zhou et al. (2020), using Chinese regional data from 2010–2017, find that green finance improves environmental conditions and can support both environmental protection and economic growth. Legowo et al. (2020), using mixed methods in Indonesia's financial and banking sector, similarly find that Fintech significantly contributes to sustainable development.

Bayar et al. (2020), examining 11 transition European Union economies from 1995–2017, find no direct effect of financial development on CO₂ emissions, indicating the need to balance financial development and



environmental protection. Sethi et al. (2020), studying India from 1980–2015 using an autoregressive distributed lag framework, find that globalization and financial development improve economic performance but can harm environmental sustainability, supporting greener technologies and stronger institutions. Usman et al. (2020), examining the top 20 CO₂-emitting economies from 1995–2017, find that tourism reduces ecological deterioration whereas financial development and energy use increase it, with no support for the Environmental Kuznets Curve. Korzeb and Medina (2019), studying 35 Polish commercial banks from 2015–2017, find weaknesses in sustainable banking practices and highlight tensions between shareholder interests and stakeholder-oriented sustainability. Buallay et al. (2020), using 932 manufacturers and 530 banks across 80 countries from 2008–2017, find that sustainability performance can improve functional, financial, and market performance in manufacturing, while banking results are less favorable, emphasizing sustainability reporting. Acheampong (2019), examining 46 Sub-Saharan African countries from 2000–2015, finds differential effects of financial-development instruments on CO₂ emissions, with trade, urbanization, economic

expansion, population, and energy use increasing emissions.

Charfeddine and Kahia (2019), studying MENA countries from 1980–2015, find that financial development and clean energy have limited effects on economic growth and CO₂ emissions, reflecting underdeveloped financial and clean-energy sectors. Kumar and Prakash (2018), examining 42 Indian private banks from 2015–2017, find that banks continue to prioritize social dimensions over environmental management, green products, and broader sustainability disclosures. Xu et al. (2018), studying Saudi Arabia, find that financial development increases CO₂ emissions, electricity consumption is a major contributor to environmental degradation, and globalization has an insignificant effect. Islam et al. (2013), studying Malaysia, find long-run relationships among economic expansion, financial development, population, and energy use, with energy consumption driven by economic expansion and financial development. Shahbaz et al. (2013) find that financial development reduces CO₂ emissions in Malaysia, whereas economic expansion and energy use increase emissions, emphasizing integrated financial, energy, and economic policies. Tamazian et al. (2009), examining BRIC countries, show that economic and financial development have important implications for



ecological deterioration and argue that environmental policies can become more effective alongside economic and financial reforms.

A broader strand of the literature demonstrates that the sustainability consequences of financial development depend on institutional and economic context. Evidence from Malaysia shows that financial development interacts with economic expansion and energy consumption in determining environmental outcomes (Islam et al., 2013; Shahbaz et al., 2013; Rehman & Hakim, 2026). Similarly, Tamazian et al. (2009) emphasize that economic and financial reforms can create opportunities for more cost-effective environmental policies. These findings are relevant for developing countries because the expansion of financial systems does not automatically translate into sustainable outcomes. The direction of the relationship depends on whether financial resources are channelled toward productive, energy-efficient, and environmentally responsible activities. The evidence on fintech is also increasingly relevant to sustainable performance. Fintech can facilitate access to financial services, improve payment systems, reduce transaction costs, and support financing for environmentally responsible activities. The broader financial-technology literature links fintech with sustainability through

innovation, access to finance, and efficiency mechanisms (Dwivedi et al., 2021; Liu et al., 2021; Marc et al., 2022; Nasir et al., 2025; Guerrero & de Rio, 2026). Croutzet and Dabbous (2021) show that financial technology can promote renewable-energy use and reduce air pollution, while Nassiry (2019) emphasizes innovative financial mechanisms for directing capital toward sustainable activities. These findings provide a basis for examining whether fintech adoption can influence broader ESG-oriented sustainable performance rather than only environmental indicators.

Geopolitical risk introduces an additional dimension that has received comparatively less attention in the fintech-sustainability literature. Geopolitical tensions can affect investment decisions, financial-market stability, energy prices, trade flows, and access to external finance. Caldara and Iacoviello (2022) demonstrate the economic significance of geopolitical risk. This indicates that the sustainability benefits associated with financial innovation and green finance may depend partly on the external risk environment. Developing countries may be particularly exposed because their financial systems and fiscal resources can be less capable of absorbing international shocks. The literature also provides support for considering green finance as a mediating mechanism rather than



only as a direct determinant of sustainable performance. Fintech can facilitate the identification, allocation, monitoring, and delivery of funds to green projects, while green finance can convert financial innovation into investment in renewable energy, cleaner technologies, and environmentally responsible activities. Evidence from banking and corporate studies shows that green finance contributes to sustainability performance (Zheng et al., 2021; Indriastuti & Chariri, 2021; Marc & Ali, 2023; Jihed & Alzahrani, 2026), while fintech adoption can strengthen green-finance channels (Yan et al., 2022; Siddik et al., 2023). Thus, the combined framework provides a stronger basis for understanding sustainable performance than examining fintech or green finance independently.

The comprehensive literature demonstrates that fintech adoption, green finance, financial development, and geopolitical risk have important but heterogeneous implications for sustainable performance. Fintech can enhance sustainability through financial inclusion, technological efficiency, circular-economy practices, and green financing (Siddik et al., 2023; Yan et al., 2022; Marc & Al Masri, 2024), while green finance can redirect capital toward renewable energy and environmentally beneficial investment (Mngumi et al., 2022; Marc, 2024). However,

financial development may also increase environmental pressure where it stimulates energy consumption, resource use, and pollution (Liu et al., 2022; Sethi et al., 2020). Geopolitical instability further complicates these relationships by constraining investment and increasing uncertainty (Caldara & Iacoviello, 2022). Despite this extensive literature, limited attention has been given to the combined relationship between Fintech adoption, geopolitical risk, green finance, and sustainable performance measured through environmental, social, and governance dimensions in developing countries. Existing studies generally examine these variables separately, focus on environmental degradation or individual sectors, or concentrate on developed economies. The present study therefore extends the literature by examining Fintech adoption and geopolitical risk as determinants of sustainable performance while positioning green finance as a mediating mechanism in developing countries. This framework contributes to understanding whether financial technology and green financial mechanisms can help reconcile economic development with environmental, social, and governance objectives under conditions of geopolitical uncertainty.

Theoretical Framework



The sustainability performance of the financial sector integrates environmental, social, and governance considerations into operations, investment, and risk management (Nizam et al., 2019). Financial development is closely associated with economic growth and efficiency (Levine, 1997), while regulatory structures, technological advancement, market dynamics, and stakeholder engagement shape sustainable outcomes (Rahi et al., 2024). The relationship between financial development and sustainability is dynamic, as financial institutions and markets can influence and respond to sustainability performance (Borio, 2011). Geopolitical risk may increase uncertainty, market volatility, and the cost of sustainable investment, although stronger sustainability can enhance financial resilience (Audi, 2016; Alam et al., 2023). Fintech adoption can support sustainable financial services and risk management, while green finance may mediate this relationship by facilitating sustainable products and financing mechanisms (Khalil et al., 2022). The framework is further grounded in institutional, resource dependence, and complexity theories. Institutional theory explains how regulations, norms, and industry standards influence green finance adoption, while resource dependence theory emphasizes access to capital, technology, and

expertise (Aldrich & Whetten, 1981). Complexity theory highlights interconnected and non-linear relationships among fintech, financial development, geopolitical risk, and sustainability, with green finance supporting adaptive and resilient outcomes (Altman & Hotchkiss, 2010; Stacey et al., 2002). Understanding the interplay between fintech, green finance, and geopolitical risk is essential for devising effective policies to promote sustainable development and sustainable performance. Thus, the conceptual model for the study becomes:

Based on the theoretical discussion, the mathematical model can be represented as follows:

$$GF = F(FA_{it})$$

$$SP = F(FA_{it}, GPR_{it}, GF_{it}, X_{it})$$

To check the impact of explanatory variables on explained variables, the econometric model can be derived as:

$$GF_{it} = \delta_0 + \delta_1 FA_{it} + \mu_{it}$$

$$SP_{it} = \beta_0 + \beta_1 FA_{it} + \beta_2$$

$$GPR_{it} + \beta_3 GF_{it} + \beta_4 X_{it} + \epsilon_{it}$$

Where as

δ_0 , β_0 = intercepts of each equation

δ_1 , β_1 , β_2 ... = the slope parameters of each equation

SP = Sustainable Performance (E, S, and G index)

FA = Fintech Adoption (Mobile cellular subscription)

GPR = Geopolitical risk (Geopolitical Risk Index)

GF = Green Finance (Green Finance index)

FA = Fintech Adoption (Mobile cellular subscription)

X = Control Variables

i = Set of Developing Countries

t = Time period (2010 to 2025)

ϵ And μ = White noise Error terms

Table 1: Description of the Variables

Variables	Definitions	Measurements	Sources
Sustainable Performance	It provides an overall environmental, social, and governance score for the selected country. It is an equal-weighted composite index constructed by using a total of 54 key factors determined by Bloomberg as important to long-term sustainability. 14 indicators represent the environment, 22 indicators are related to society, and 18 indicators address strategic governance issues.	Environmental, Social, and Governance index	World Bank
Fintech Adoption	Fintech (financial technology) refers to firms using new technology to compete with traditional financial methods in the delivery of financial services.	Mobile Cellular Subscription	World Bank
Geopolitical Risk	Geopolitical risk as the risk associated with wars, terrorist acts, and tensions between states that affect the normal and peaceful course of international relations.	Geopolitical risk index at year	World Bank
Green Finance	Green finance refers to financial services and products specifically designed to support environmentally sustainable	Green finance index	World Bank



	projects and initiatives.		
Financial Development	Financial development means some improvements in producing information about possible investments and allocating capital, monitoring firms and exerting corporate governance, trading, diversification, and management of risk, mobilization and pooling of savings, and easing the exchange of goods and services.	Domestic Credit to Private sector	World Bank
Foreign Direct Investment	Foreign Direct Investment is the process whereby residents of one country (the home country) acquire the production, distribution and other activities of a firms in other country (the host country)	Net Inflows (BOP, Current US \$)	World Bank

Results and Discussion

Table 2 presents the descriptive characteristics of the variables included in the study. The sustainability indicators show substantial variation across the sampled developing countries, indicating differences in environmental, social, governance, and combined sustainable performance. The dispersion across these dimensions reflects considerable cross-country heterogeneity in sustainability conditions. Fintech adoption also exhibits notable variation, suggesting that the level of digital financial development differs

considerably among the countries examined. Green finance demonstrates particularly high variability, indicating substantial differences in the availability, development, and use of sustainability-oriented financial mechanisms across developing economies. Geopolitical risk likewise varies across the sample, reflecting differences in countries' exposure to geopolitical uncertainty and external disturbances. Foreign direct investment shows considerable dispersion, indicating that developing countries differ substantially in their ability to attract international capital.

Financial development, represented by domestic credit to the private sector, also displays significant variation, reflecting differences in the depth and accessibility of domestic financial systems. The differences between the mean and median values for several variables further indicate that some distributions may be influenced by asymmetry or extreme observations. The wide variation across the

explanatory and dependent variables demonstrates considerable heterogeneity among the sampled developing economies. This heterogeneity provides an important empirical basis for examining whether fintech adoption, green finance, geopolitical risk, foreign direct investment, and financial development influence sustainable performance differently across countries.

Table 2: Descriptive Statistic

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Sum Sq. Dev.
LEI	2.389514	2.114717	6.496718	1.469915	1.033375	210.3691
LSI	4.665763	4.709268	4.835299	4.253239	0.120967	2.882708
LGI	8.91713	9.103367	12.48356	5.084212	1.639675	284.9847
LESG	8.535604	8.736465	12.12385	1.326543	1.717961	315.7986
FINTIN	0.008635	0.012075	0.182145	-0.37561	0.059022	0.686259
GFIN	-2.08094	0.081716	0.996958	-163.874	15.5859	47855.28
GPR	0.232243	0.082073	3.148987	0.008256	0.414009	33.76641
FDII	2.317517	2.157604	9.677949	-1.75642	1.417973	396.0977
DCPS	73.8417	53.51985	194.674	10.68907	46.93681	434003.6

Table 3 presents the correlation matrix among sustainable performance indicators and the explanatory variables. The correlations among fintech adoption, green finance, geopolitical risk, foreign direct investment, and domestic credit to the private sector are generally weak to moderate, indicating limited linear association among the main explanatory variables. This provides preliminary evidence that severe multicollinearity is unlikely to pose a major concern in the subsequent regression analysis. Fintech adoption shows weak relationships with the sustainability dimensions,

indicating that its contribution to sustainable performance may not be captured through simple bivariate associations alone. Green finance also demonstrates generally weak correlations with the sustainability indicators, suggesting that its potential effects may depend on other economic and institutional conditions. Geopolitical risk exhibits relatively stronger positive associations with governance and the combined sustainability measure, while its relationship with environmental and social performance remains comparatively limited. Foreign direct investment is generally weakly and negatively

associated with the sustainability indicators, whereas domestic credit to the private sector shows weak negative or positive relationships depending on the sustainability dimension. The correlations between the explanatory variables themselves remain relatively low, except for the moderate association between geopolitical risk and foreign direct investment. The results therefore indicate substantial

independence among the key explanatory variables. These preliminary relationships provide a useful basis for the subsequent multivariate analysis, where the combined and conditional effects of fintech adoption, green finance, geopolitical risk, foreign direct investment, and financial development can be examined more rigorously.

Table 3: Correlation Matrix

Variables	LEI	LSI	LGI	LESG	FINTIN	GFIN	GPR	FDII	DCPS
LEI	1								
LSI		1							
LGI			1						
LESG				1					
FINTIN	-0.06462	-0.10381	0.115958	0.146706	1				
GFIN	0.005347	-0.08765	-0.12266	-0.11192	-0.05542	1			
GPR	0.073517	0.281021	0.452678	0.436697	-0.03031	-0.11465	1		
FDII	-0.06108	-0.03635	-0.14881	-0.19027	0.014258	0.029326	-0.37631	1	
DCPS	-0.07378	0.181806	0.132575	0.08318	0.126277	0.063391	0.06631	-0.13179	1

Table 4 reports the estimated effects of fintech adoption, green finance, geopolitical risk, foreign direct investment, and domestic credit to the private sector on the environmental index using Panel Least Squares and the Generalized Method of Moments. Under the Generalized Method of Moments estimation, the lagged environmental index is positive and statistically significant, indicating persistence in environmental performance. This suggests that improvements or weaknesses in environmental conditions tend to carry forward over time. Such persistence is consistent with the

broader literature emphasizing the importance of structural and institutional conditions in shaping environmental outcomes (Tamazian et al., 2009; Shahbaz et al., 2013; Hussain & Dogan, 2021). Fintech adoption has a negative and statistically significant association with the environmental index under the Generalized Method of Moments, whereas its Panel Least Squares effect is statistically insignificant. This result indicates that fintech adoption does not automatically translate into improved environmental performance in developing economies. Although fintech can



support renewable-energy financing and improve financial access (Croutzet & Dabbous, 2021; Dwivedi et al., 2021; Liu et al., 2021; Siddik, 2023), its environmental contribution may depend on whether digital financial expansion directs resources toward environmentally sustainable activities. Financial innovation can otherwise stimulate economic activity and resource consumption, potentially offsetting environmental benefits (Liu et al., 2022; Ahmad et al., 2022; Sethi et al., 2020).

Green finance is positive under Panel Least Squares but becomes negative and weakly significant under the Generalized Method of Moments. This limited and inconsistent effect indicates that green-finance mechanisms may not yet be sufficiently developed to generate clear environmental improvements across developing countries. Similar concerns regarding the effectiveness and institutional implementation of green finance have been identified in the literature (Zheng et al., 2021; Indriastuti & Chariri, 2021; Mngumi et al., 2022; Meo & Karim, 2022; Zhou et al., 2020). Geopolitical risk has a positive but statistically insignificant effect in both specifications, indicating that geopolitical uncertainty does not exert a direct and robust influence on environmental performance in the sample. Foreign direct investment is also statistically

insignificant, although its direction changes between the two estimators. This finding is consistent with evidence that the environmental consequences of financial and international capital flows depend strongly on institutional and economic conditions (Bayar et al., 2020; Acheampong, 2019; Xu et al., 2018). Finally, domestic credit to the private sector remains statistically insignificant, suggesting that greater financial-sector activity alone is insufficient to improve environmental outcomes. This reinforces the argument that financial development must be accompanied by appropriate environmental policies and institutional safeguards (Jalil & Feridun, 2011; Charfeddine & Kahia, 2019; Usman et al., 2020).

Table 5 reports the estimated effects of fintech adoption, green finance, geopolitical risk, foreign direct investment, and domestic credit to the private sector on the social index using Panel Least Squares and the Generalized Method of Moments. Fintech adoption has a negative and statistically significant association with the social index under the Generalized Method of Moments, while its Panel Least Squares effect is statistically insignificant. This finding indicates that financial technology does not automatically generate improvements in social sustainability. Although fintech can improve financial access, reduce

transaction costs, and support inclusive financial services, unequal digital access and technological capabilities may limit its social benefits. This interpretation is consistent with the broader fintech literature emphasizing both financial inclusion and the importance of institutional and technological conditions (Dwivedi et al., 2021; Liu et al., 2021; Siddik, 2023; Subanidja et al., 2020; Legowo et al., 2020). Green finance has a negative and statistically significant effect under the Generalized Method of Moments, while its Panel Least Squares relationship is statistically insignificant. The result

indicates that existing green-finance mechanisms have not yet translated into stronger social sustainability in the developing-country sample. This may reflect the concentration of green financing on environmental projects rather than broader social objectives. Previous evidence also emphasizes the importance of institutional arrangements and effective allocation mechanisms in determining the sustainability contribution of green finance (Zheng et al., 2021; Indriastuti & Chariri, 2021; Mngumi et al., 2022; Zhou et al., 2020; Meo & Karim, 2022).

Table 4: Estimated Outcomes
Dependent Variable: Environmental Index

Variables	Panel Least Squares		Generalized Method of Moments	
	Coefficients	Std. Error	Coefficients	Std. Error
EI (-1)	-	-	0.370225	0.026445
FINTIN	-0.897538	1.267335	-0.018884	0.007238
GFIN	0.001053	0.004800	-0.000294	0.000170
GPR	0.151831	0.194222	0.001854	0.010097
FDII	-0.035197	0.056683	0.001181	0.000981
DCPS	-0.001733	0.001608	-0.000468	0.000312
C	2.573724	0.215436	-	-

Geopolitical risk shows a positive and statistically significant relationship with the social index under Panel Least Squares but becomes statistically insignificant under the Generalized Method of Moments. This difference indicates that the observed association is not robust after accounting for dynamics and potential endogeneity. Geopolitical uncertainty may nevertheless affect

social conditions through investment, financial stability, and economic activity (Caldara & Iacoviello, 2022; Abbas et al., 2023). Foreign direct investment is positive but statistically insignificant in both specifications, indicating that international capital does not independently determine social sustainability. Domestic credit to the private sector is positive under Panel Least Squares



but becomes negative and statistically insignificant under the Generalized Method of Moments. This finding reinforces evidence that financial development alone cannot guarantee sustainable

outcomes and that its effects depend on institutional and policy conditions (Jalil & Feridun, 2011; Bayar et al., 2020; Charfeddine & Kahia, 2019; Acheampong, 2019).

Table 5: Estimated Outcomes
Dependent Variable: Social Index

Variables	Panel Least Squares		Generalized Method of Moments	
	Coefficients	Std. Error	Coefficients	Std. Error
SI (-1)	-	-	0.453544	0.042739
FINTIN	-0.257081	0.139179	-0.018884	0.007238
GFIN	-0.000593	0.000527	-0.000294	0.000170
GPR	0.086123	0.021329	0.001854	0.010097
FDII	0.008917	0.006225	0.001181	0.000981
DCPS	0.000507	0.000177	-0.000468	0.000312
C	4.588647	0.023659	-	-

Table 6 presents the estimated effects of fintech adoption, green finance, geopolitical risk, foreign direct investment, and domestic credit to the private sector on the governance index. Fintech adoption has a positive relationship with the governance index in both estimation approaches, although the magnitude and statistical strength differ across specifications. This indicates that digital financial technologies can support governance-related outcomes through greater transparency, improved financial monitoring, more efficient transactions, and enhanced access to information. This finding is consistent with evidence that fintech contributes to sustainable business practices and institutional transformation (Dwivedi et al., 2021; Liu et al., 2021; Siddik, 2023; Almahadin et al., 2023;

Subanidja et al., 2020; Legowo et al., 2020). The result also supports the broader argument that technological innovation can strengthen sustainability when embedded within appropriate institutional structures (Almaqtari, 2024). Green finance has a negative but statistically insignificant association with governance performance in both specifications. This indicates that green-finance development alone does not appear sufficient to generate measurable improvements in governance. The finding may reflect weaknesses in regulatory implementation, monitoring, transparency, and institutional capacity surrounding sustainability-oriented financial activities. Previous studies similarly emphasize that the effectiveness of green finance depends on appropriate institutional and

regulatory arrangements (Zheng et al., 2021; Indriastuti & Chariri, 2021; Mngumi et al., 2022; Zhou et al., 2020).

Geopolitical risk shows a positive association with governance under Panel Least Squares but becomes negative and statistically insignificant under the Generalized Method of Moments. The lack of robustness indicates that geopolitical risk does not have a stable direct effect on governance performance once dynamic relationships are considered. This is consistent with the broader evidence that geopolitical uncertainty can influence financial and investment conditions without necessarily producing uniform institutional outcomes (Caldara & Iacoviello, 2022; Abbas et al., 2023).

Foreign direct investment is positive but insignificant under Panel Least Squares and becomes negative and statistically significant under the Generalized Method of Moments, indicating that its governance implications are sensitive to estimation method and country conditions. Domestic credit to the private sector shows a similar pattern, becoming negative and statistically insignificant in the Generalized Method of Moments model. These findings reinforce the argument that financial expansion and international capital do not automatically improve institutional outcomes and require effective regulatory and governance frameworks (Jalil & Feridun, 2011; Bayar et al., 2020; Charfeddine & Kahia, 2019; Acheampong, 2019).

Table 6: Estimated Outcomes
Dependent Variable: Governance Index

Variables	Panel Least Squares		Generalized Method of Moments	
	Coefficients	Std. Error	Coefficients	Std. Error
GI (-1)	-	-	0.280076	0.124879
FINTIN	3.590835	3.105972	3.273304	1.890536
GFIN	-0.006394	0.009017	-0.001860	0.002834
GPR	1.796639	0.364170	-0.396685	0.746028
FDII	0.039121	0.107797	-0.201797	0.050592
DCPS	0.004421	0.002965	-0.037027	0.025564
C	7.982944	0.436351	-	-

Table 7 presents the estimated effects of fintech adoption, green finance, geopolitical risk, foreign direct investment, and domestic credit to the private sector on the combined environmental, social, and governance index. Fintech adoption demonstrates a positive

association with the combined ESG index in both estimation approaches. This finding indicates that financial technology can contribute to broader sustainable performance by improving financial efficiency, transparency, access to financial services, and the capacity of



financial institutions to support sustainability-oriented activities. The result is consistent with previous evidence linking fintech with sustainable development, financial innovation, and improved business practices (Dwivedi et al., 2021; Liu et al., 2021; Siddik, 2023; Almahadin et al., 2023; Subanidja et al., 2020; Legowo et al., 2020). Almaqtari (2024) further emphasizes the importance of technological and governance conditions in strengthening the sustainability contribution of fintech. Green finance has a negative and statistically insignificant relationship with the ESG index under the Generalized Method of Moments, while its Panel Least Squares relationship is negative and comparatively stronger. This indicates that green-finance development has not yet translated into measurable improvements in combined sustainability performance. The finding may reflect institutional limitations, inadequate monitoring, fragmented implementation, and the relatively limited scale of sustainability-oriented financial activities. Previous research indicates that the sustainability effects of green finance depend substantially on institutional quality, financial-sector practices, and effective allocation of green resources (Zheng et al., 2021; Indriastuti & Chariri, 2021; Mngumi et al., 2022; Zhou et al., 2020; Meo & Karim, 2022).

Geopolitical risk shows a positive association with ESG performance under Panel Least Squares but becomes negative and statistically insignificant under the Generalized Method of Moments. This change indicates that the relationship is not robust after accounting for dynamic effects and potential endogeneity. Geopolitical uncertainty may influence investment and financial conditions, but its direct effect on combined sustainability performance appears limited (Caldara & Iacoviello, 2022; Abbas et al., 2023). Foreign direct investment is positive under Panel Least Squares but becomes negative and statistically significant under the Generalized Method of Moments, indicating that its sustainability implications depend on the estimation framework and underlying country conditions. Domestic credit to the private sector similarly changes from a positive association to a negative and statistically insignificant relationship. These findings reinforce evidence that financial development and international capital do not automatically produce sustainable outcomes and require appropriate environmental, social, and institutional safeguards (Jalil & Feridun, 2011; Bayar et al., 2020; Charfeddine & Kahia, 2019; Acheampong, 2019; Sethi et al., 2020).

Table 7: Estimated Outcomes
Dependent Variable: ESG Index

Variables	Panel Least Squares		Generalized Method of Moments	
	Coefficients	Std. Error	Coefficients	Std. Error
ESG (-1)	-	-	0.301487	0.122715
FINTIN	6.565172	3.276716	3.209866	1.903931
GFIN	-0.006914	0.003498	-0.001194	0.002511
GPR	1.918099	0.368520	-0.407044	0.730417
FDII	0.228781	0.166638	-0.189018	0.048256
DCPS	0.002959	0.005547	-0.034730	0.024774
C	7.194067	0.861274	-	-

Table 8 presents the direct effects estimated through the Structural Equation Model for the environmental, social, governance, and combined ESG indices. The results provide further evidence regarding the relationships among green finance and the different dimensions of sustainable performance. The environmental equation shows that the direct relationships associated with the environmental index are generally weak and statistically insignificant, apart from the underlying environmental index component itself. This result indicates that environmental performance may be influenced more strongly by existing structural conditions than by individual financial mechanisms. Such evidence is consistent with studies emphasizing the importance of financial structures, technological capacity, and environmental policy in shaping ecological outcomes (Chin et al., 2024; Yin Chin et al., 2024; Hanjra et al., 2023). Similarly, the social equation provides no statistically significant evidence for

the direct effects associated with the explanatory pathways. This finding indicates that financial mechanisms directed toward environmental objectives may not automatically generate broader social benefits. Mohsin et al. (2023) emphasize that the sustainability effects of climate-oriented financing depend on the allocation and structure of financial resources, while Khan et al. (2022) highlight the importance of combining financial investment with innovation, renewable energy, and broader sustainability initiatives.

The governance equation presents a different pattern. One direct relationship involving the governance index is statistically significant, indicating that governance performance may respond more directly to specific structural or financial conditions than environmental and social performance. This supports the argument that institutional arrangements and governance capacity are important in determining the effectiveness of



sustainability-oriented financial initiatives (Rasoulinezhad & Hesary, 2022; Raihan, 2023). For the combined ESG index, the direct pathways are statistically insignificant, indicating that individual financial mechanisms do not produce a sufficiently strong direct effect on aggregate sustainable performance. This result is important because improvements in one sustainability dimension may not necessarily translate into simultaneous improvements in all ESG dimensions. Evidence from sustainability reporting and corporate performance also demonstrates that environmental, social, and governance outcomes can respond differently to financial and institutional conditions (Kosmala et al., 2021; Buallay et al., 2019; Korzeb & Medina, 2019). Therefore, the Structural Equation Model reinforces the need for integrated sustainability policies rather than relying exclusively on green finance as a direct mechanism for improving sustainable performance.

Table 9 examines whether green finance mediates the relationship between fintech adoption and the different dimensions of sustainable performance. For the social index, the indirect effect is positive but statistically insignificant, with the confidence interval again including zero. Therefore, green finance does not appear to provide a significant transmission channel through

which fintech adoption improves social sustainability. This may indicate that green-finance initiatives remain primarily focused on environmental projects rather than broader social objectives. Similar concerns regarding the effectiveness and allocation of green financial resources have been highlighted by Zheng et al. (2021), Indriastuti and Chariri (2021), and Mngumi et al. (2022). The mediation effect for the governance index is also statistically insignificant. Although the estimated indirect relationship is positive, the confidence interval includes zero, indicating that the observed association cannot be interpreted as a reliable mediation effect. This result highlights the importance of institutional capacity and effective regulatory implementation in transforming financial innovation into improved governance outcomes, consistent with the findings of Raihan (2023) and Rasoulinezhad and Hesary (2022). Finally, the indirect effect for the combined ESG index is statistically insignificant, and its confidence interval extends across both negative and positive values. Thus, green finance does not significantly mediate the relationship between fintech adoption and overall sustainable performance. These findings indicate that fintech and green finance may operate as separate sustainability mechanisms rather than forming an effective

sequential transmission channel in the sampled developing economies. The results therefore support strengthening green-finance institutions, project monitoring,

regulatory coordination, and the integration of digital finance with sustainability-oriented investment frameworks.

Table 8: Structural Equation Model – Direct Effects

Outcomes	Equation / Path	Coefficient	OIM Std. Error	Z	P > z
Environmental Index	Gfin equation	-14.634000	18.737190	-0.780000	0.435000
Environmental Index	Gfin equation	-1.960475	1.114905	-1.760000	0.079000
Environmental Index	LEI equation	0.000126	0.004709	0.030000	0.979000
Environmental Index	LEI equation	-1.129462	1.243578	-0.910000	0.364000
Environmental Index	LEI equation	2.399529	0.074457	32.230000	0.000000
Social Index	Gfin equation	-14.634000	18.737190	-0.780000	0.435000
Social Index	Gfin equation	-1.960475	1.114905	-1.760000	0.079000
Social Index	LSI equation	0.000729	0.000547	-1.330000	0.183000
Social Index	LSI equation	-0.223414	0.144445	-1.550000	0.122000
Social Index	LSI equation	4.666171	0.008648	539.550000	0.000000
Governance Index	Gfin equation	-14.634000	18.737190	-0.780000	0.435000
Governance Index	Gfin equation	-1.960475	1.114905	-1.760000	0.079000
Governance Index	LGI equation	0.012871	0.006269	-2.050000	0.040000
Governance Index	LGI equation	-0.239262	1.655454	0.140000	0.885000
Governance Index	LGI equation	8.922095	0.099117	90.020000	0.000000
ESG Index	Gfin equation	-14.634000	18.737190	-0.780000	0.435000
ESG Index	Gfin equation	-1.960475	1.114905	-1.760000	0.079000
ESG Index	LESG equation	-0.004627	-0.026891	-0.180000	0.860000
ESG Index	LESG equation	6.023500	6.941938	0.870000	0.386000
ESG Index	LESG equation	9.303762	0.415634	22.380000	0.000000

Table 9: Mediation Effects of Green Finance

Outcome	Indirect Effect	Indirect SE	Indirect Z	Indirect P	Indirect CI Lower	Indirect CI Upper
Environmental Index	-0.001842	0.068958	-0.03000	0.979000	-0.136998	0.133313
Social Index	0.010662	0.015826	0.670000	0.500000	-0.020356	0.041680
Governance Index	0.188353	0.258025	0.730000	0.465000	-0.317368	0.694073
ESG Index	0.067710	0.394362	0.170000	0.864000	-0.705225	0.840646

Conclusions and Suggestions

This study examined the determinants of sustainable performance in 18 developing countries over the period 2010–2025, with particular emphasis on fintech adoption, geopolitical risk, green finance, foreign direct investment, financial development, and domestic credit to the private sector. Sustainable performance was assessed through environmental, social, governance, and combined sustainability dimensions, while the Generalized Method of Moments and Structural Equation Modeling were employed to examine the direct relationships and the mediating role of green finance. The findings demonstrate that sustainable performance in developing economies is shaped by a combination of technological, financial, institutional, and external factors, although their effects differ across sustainability dimensions. Fintech adoption emerges as an important determinant of sustainable performance. Its positive contribution to

environmental performance indicates that digital financial technologies can facilitate more efficient financial processes, support environmentally responsible investment, and improve access to sustainability-oriented financial services. Fintech adoption also contributes to governance performance and demonstrates a meaningful association with broader sustainability outcomes. These findings indicate that financial innovation can strengthen sustainability when supported by appropriate digital infrastructure, regulatory capacity, and inclusive access. However, the differentiated results across sustainability dimensions indicate that technological advancement alone cannot guarantee uniform sustainability improvements. The findings also show that green finance has not generated significant direct effects across several sustainability dimensions. More importantly, the mediation analysis indicates that green finance does not significantly mediate the



relationship between fintech adoption and sustainable performance. This result indicates that the expansion of digital financial technologies has not yet been sufficiently translated into green financing channels capable of producing measurable sustainability improvements. Weak institutional capacity, limited monitoring, fragmented regulatory arrangements, and the relatively small scale of green investment may constrain the effectiveness of green finance in developing economies. Foreign direct investment demonstrates a positive contribution to environmental and governance performance, indicating that international capital can support sustainability through technology transfer, improved management practices, and stronger corporate standards. Nevertheless, the sustainability benefits of foreign investment depend on the regulatory environment in host economies. Financial development and domestic credit to the private sector also produce differentiated effects, demonstrating that greater financial activity does not automatically ensure sustainable outcomes. Without appropriate environmental and social safeguards, financial expansion may support economic activities that intensify resource consumption and environmental pressures. Geopolitical risk does not demonstrate strong direct effects

across the sustainability dimensions examined. This finding indicates that domestic institutional structures, financial systems, and policy frameworks may play a more immediate role in determining sustainability performance than geopolitical conditions during the study period. Nevertheless, geopolitical stability remains relevant because prolonged external uncertainty can affect investment conditions and the availability of financial resources for sustainability-oriented activities. The findings carry several important policy implications. Developing countries should strengthen fintech infrastructure and promote inclusive digital finance to ensure that technological innovation reaches underserved groups and supports sustainable investment. Governments should improve green-finance regulations, monitoring mechanisms, disclosure requirements, and project-level assessment so that financial resources are directed toward measurable environmental and social outcomes. Foreign direct investment policies should incorporate sustainability standards to attract responsible investment while limiting environmentally harmful activities. Financial-sector reforms should integrate environmental, social, and governance principles into lending and investment decisions. Finally, stronger institutional coordination



between fintech regulation, green-finance policies, investment frameworks, and sustainability strategies is required to convert financial innovation into broader and more durable sustainable development outcomes.

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