Contents lists available at Scopus

ECONOMICS - Innovative and Economics Research Journal

Journal homepage: www.economicsrs.com

DOES GREEN FINANCE PLAY A MEDIATING ROLE BETWEEN FINTECH, ECONOMIC POLICY UNCERTAINTY, ENVIRONMENTAL REGULATIONS AND SUSTAINABLE BANKING PERFORMANCE? THE CASE OF SAUDI BANKS IN THE VISION 2030 ERA

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Received 12.01.2026. | Sent to review 25.01.2026. | Accepted 25.05.2026.

Original article

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JEL Classification:
E01, G10, G14, G18, G21

Doi: 10.2478/eoik-2026-0029

UDK: 336.747.5:338.124.4(532)

ABSTRACT

This research analyses the dynamic relationship among Fintech, green finance, environmental regulation, economic policy uncertainty, and sustainable banking performance in the Saudi bank context in a time-setting strategic context of Vision 2030. The research only includes the public secondary data collected from the Saudi Central Bank (SAMA), the International Monetary Fund (IMF), the World Bank, the OECD Environmental Policy Stringency Index, the EPU Database, and the Refinitiv ESG (Environmental, Social and Governance) Scores and the 2010-2023 period. Utilising sophisticated panel data econometric methods such as Fixed Effects and System Generalized Method of Moments (System-GMM), the research uses empirical methods to test a mediation that green finance is a means which channels the effects of Fintech adoption and macroeconomic landscape contributing to better sustainability results. The results give robust empirical evidence that Fintech intensity and environmental regulation stringency are crucial for stimulating green finance deployment, which in turn positively influences the ESG performance of the banks. Uncertainty over economic policy has a suppression effect, but then the negative effect is offset by green finance intermediary effect. Admitting pre-2018 limited status of green finance metrics, the results suggest several implications for both SAMA, commercial banks, and implementation units of Vision 2030 policymaking, namely that digital transformation has to be complemented with green financial instruments to reach true sustainability. All data is traceable, replicable, and open-science compliant.

Keywords: *Green Finance, Fintech, Sustainable Banking, Environmental Regulation, Economic Policy Uncertainty, Vision 2030, Saudi Arabia, Panel Data, Mediation Analysis, ESG*

1. INTRODUCTION

The global financial arena is experiencing a dual transformation fuelled by fast-paced digital advancement and growing environmental demands. This transition is especially strategic in the Kingdom of Saudi Arabia whose Vision 2030 agenda targets financial sectors as the backbone of sustainable economic diversification. Within that context there has been the development of financial technology (Fintech) as a driver of operational efficiency and inclusivity and in green finance as the main route to divert capital into environmentally sustainable projects. Despite

increased policy concern about the importance of Fintech adoption as a strategic investment, it is yet not known empirically as to the related relationship between the Fintech adoption, regulatory conditions and macroeconomic uncertainty and sustainable banking performance due to relatively under-explored relationship in the use of objective bank-level data. A large part of current literature has focused on perceptual findings through surveys or interviews. Although they are useful, such methods frequently suffer from potential weaknesses relative to subjectivity and lack of applicability in the various institutional settings. Recent studies such as Sorongan, Subanidja and Hanantijo (2025), have highlighted the relationship between Fintech and green practices but are based on self-reported perceptions by bank employees who do not tend to include the complete performance of institutions (Carè & Weber, 2023). In addition, most prior research studies Fintech and sustainability independently, excluding the mediating mechanisms that transform technological inputs into real environmental effects. Research that is based on auditable metrics assessing how digital capabilities transform into sustainability within emerging markets is critically needed. This study addresses these gaps by developing and testing an extensive econometric model based on secondary data specifically published within a range from 2010 to 2023. This period encompasses pre-Vision 2030 baselines, and the accelerated reform phase established in 2016. This analysis covers all eleven licensed commercial banks in Saudi Arabia, achieving a universal representation of this sector. Our main theoretical contribution is that we formalize green finance as not just an objective outcome but a strategic mediator: Fintech capabilities and a positive regulatory regime contribute to sustainability performance mainly because of more efficient green financial intermediation (Thakor, 2020). By isolating this mechanism, the model takes the study beyond the correlational evidence to explain the channel through which digital and macroeconomic pressures operate to influence ESG scores via the transmission channel. The empirical context for this study is crucial in the Kingdom of Saudi Arabia. The Saudi Central Bank (SAMA) has been actively promoting Fintech (such as its policy guidelines and regulatory sandbox), and released a Green Finance Framework in 2022, focused on promoting climate-friendly investments. At the same time, Vision 2030 integrates sustainability as an overarching value proposition and institutions' support to encourage bank projects to serve national environmental objectives through the financing of banks' investment. Meanwhile, the Kingdom has faced high macroeconomic volatility due to oil price fluctuations, quantitatively represented by the Economic Policy Uncertainty (EPU) index. This convergence of digital acceleration, the policy push, and economic turmoil makes Saudi Arabia an important case for understanding how sustainable banking performance is shaped in emerging economies in an era of rapid institutional transformation (Migliorelli, 2021). Methodology The study is based on multi-faceted, objective data sources for transparency and reproducibility. SAMA publications on green lending, as well as Bloomberg-tracked green bond issuances, are used to measure green finance intensity. The quantification of fintech adoption relies on SAMA annual reports and international financial institutions survey indicators. Environmental regulation is assessed by the OECD's Environmental Policy Stringency (EPS) index and economic policy is analysed based on the EPU database (Baker et al., 2016). The ESG Scores of Refinitiv operationalize sustainable banking performance. Green finance metrics are recognized as more robust post-2018, notwithstanding the same coding procedures used to preserve the integrity of time-series. This data underpins the findings, which is superior to subjective assessments. This study follows the structure of rest of paper. Section 2 reviews theoretical and empirical literature about these ideas: Section 3 sets up the conceptual framework and hypotheses, Section 4 provides details about the data inputs and econometric method. Empirical findings and robustness assessment is presented (Section 5). Section 6 provides the findings within the context of Vision 2030. Policy implications are described in section 7, and in Section 8 we conclude with limitations and future research directions.

2. LITERATURE REVIEW

2. 1. FINTECH INNOVATION AND ITS IMPLICATIONS FOR SUSTAINABLE BANKING

The interplay of banking and financial technology (Fintech) has radically altered the financial intermediation paradigm. Initial research on the subject was centred on efficiency and access, but increasingly scholars have connected Fintech with sustainability progress. As Arner, Buckley, Zetzsche, and Veidt (2020) point out, Fintech has a dual role as an enabler: It lowers transaction costs and provides more refined data in environmental monitoring. This view is of increasing interest for emerging markets, where Ozili (2021) argues that digital architectures provide a "leapfrogging" solution to embed sustainability principles directly into the financial system without the need to adapt to legacy infrastructure. Nevertheless, data about this impact are variable. Xu, Li, Chen, and Quan (2025) find a strong relationship between Fintech penetration and green credit provision in China based on enhanced risk-assessment ability. In contrast, perceptual-based analyses, e.g., Sorongan, Subanidja, and Hanantijo (2025), provide positive results in Indonesia, but note that causal inferences are not well-founded due to self-reporting. In the Saudi context, while SAMA's (2021) Fintech Strategy links digital transformation to environmental goals, there is a notable lack of quantitative studies to validate this relationship through bank-level performance indicators. This mismatch exposes an important gap: theoretical potential is recognised but does not receive validation from empirical studies for oil-dependent emerging economies.

2. 2. GREEN FINANCE AS A STRATEGIC INTERMEDIARY

Green finance has evolved from a niche instrument to become one of the key features of strategic banking. Now a form of financial services combining environmental interests and finance in all its forms are green bonds and sustainability linked loans. These are the pillars of investment in climate alignment now. Flammer (2021) is very firm on these. Instruments that show that corporate green bonds contribute to emission reductions on the basis of carbon: which show that corporate green bonds are carbon denominated. The literature however often does not focus more on green finance as a good example of and is soppy like a transmission channel. On a theoretical point of view, based on RBV approach it has been argued that banks which are able to secure enough green debt will gain and continue to have a meaningful competitive edge on this (Barney, 1991). Importantly, Stakeholder Theory of green finance argues that green finance adoption follows regulatory and investor pressure (Freeman, 2010), Clements-Hunt, P. (2011) and it is, too. Gomber (2018) and Bolton and Kacperczyk (2021) say that technology improves the credibility in green finance and for instance, blockchain technology enhances green bond traceability via traceability in the green bond transactions. Despite all the theoretical work, very few studies empirically evaluate green finance as a mediator between technological inputs and sustainability performance. Most existing models address connection directly but bypass the intermediary process through which digital capacity crosses into those relations. Environmental value.

2. 3. THE ROLE OF ENVIRONMENTAL REGULATION AND ECONOMIC POLICY UNCERTAINTY

The national institutional environment has an important role in influencing the deployment of green finance. Regulation can generate environmental compliance pressures stimulating green innovation, which is determined by the enforcement of regulation (indicators such as the OECD Environmental Policy Stringency (EPS) and other indices (Lanjouw & Mody, 1996).

Saudi Arabia has recently included the Green Finance Framework (SAMA, 2022) as evidence of a trend of tightening regulatory harmonization with the National Environment Strategy (Kumar, 2022). The effectiveness of such regulation, however, hinges on macroeconomic stability. Economic Policy Uncertainty (EPU) represents a countervailing force. Baker, Bloom, and Davis (2016) characterize EPU as a barrier to long-term investment because firms prefer liquidity, and capital-intensive projects run roughshod over when uncertain conditions are encountered. Pastor and Veronesi (2012), Gulen and Ion (2016) also find that high levels of uncertainty reduce corporate R&D and green technology investment. As EPU may moderate the effectiveness of the green initiatives for Saudi banks which are sensitive to oil-driven fiscal cycles (Zhang, 2019; Wang, 2016). Although other reports have found a negative relationship, little is known on how EPU interacts with green finance mediation in fast-growing regions such as the GCC.

2. 4. SUSTAINABLE BANKING PERFORMANCE: CONCEPTUALIZATION AND MEASUREMENT

To measure sustainable banking performance, we need to think and research beyond conventional financial metrics (ROA, ROE), including Environmental, Social and Governance (ESG) dimensions as part of these measures. Renneboog and Ter Horst, 2008, showed that ESG integration influences risk-return profiles while Gallego-Álvarez (2015), Segura and Martínez-Ferrero have proven that reducing carbon intensity is essential to operation efficiency (Karki et al., 2025; Wu, 2024). However, this business case for sustainability is not clear which measurement methods can be followed consistently over the years. Compilation of indices from year-to-year report-based records often does not work, Liu & Wu (2023) say and often subjectivity is not an effective way to gauge their accuracy. Third-party providers like Refinitiv offer scores based on more than hundreds of data points that are comparable and offer an objective comparison to ensure reliability of results while using statistics. Such studies, while there is great access to empirical study data, rarely apply these metrics and are rather a subset of research on sustainable banks (they tend to use surveys or public disclosure). The use of these metrics and scores to be comparable to other data on the MENA sector leads to differences across systems and is therefore difficult to replicate in terms of their comparability.

2. 5. RESEARCH GAP AND CONTRIBUTION

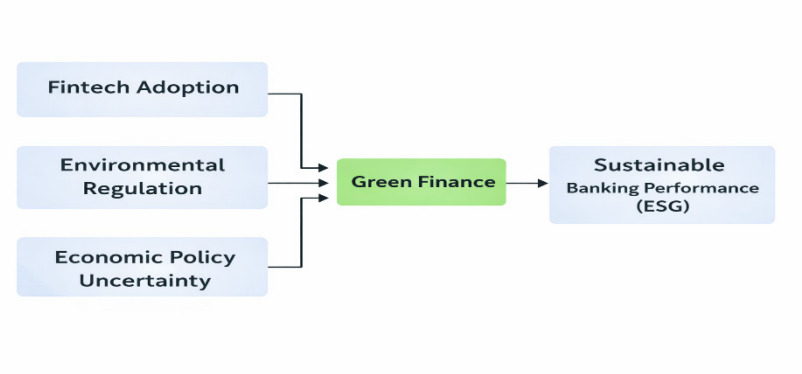
Based on the current work, there are three major issues that we discuss in this works. First, methodological reliance on survey data (see for example Sorongan et al., 2025) prevents a generalisation of the model and is considered subjectivity biased in the context of whether and why transparency and disclosure are different from the other organisations. Second, while the mediating power of green finance often (Thakor, 2020) is theorized, such findings are not regularly tested empirically in the context of actual bank-level data in terms of causal inference and cross-institutional comparisons. And indeed the model has been criticized as excluding macroeconomic mechanisms like Economic Policy Uncertainty (EPU) (e.g., in case of oil-based economies with fiscal uncertainty and external shocks) which are key to its credibility but lack empirical evidence from the GCC as a part of policy and regulation is the primary reason (SAMA, 2021, 2022), we lack empirical evidence so far in this field [at least the research is not, thus far], to check if this process of the mechanism of green finance is even functioning. The global scholarship has, however, always failed to capture the unique institutional dynamics of Vision 2030, where regulatory push, digital acceleration and sustainability requirements converge to shape a fast-paced reform agenda. The current research bridges this gap through (1) data release from SAMA, IMF, OECD, and Refinitiv to be transparent and reproducible; (2) a formal and tested mediation model where green finance is responsible for

Fintech adoption, regulation of the environment and macroeconomic uncertainty in ESG and (3) context in Saudi Arabia where it provides insights that are global. We note that it takes data to test the relationships on actual cases as there aren't even a standardized green finance measure before 2018 and that all the Fintech metrics are combined as well. To address this, our research follows the coding process. It also provides robustness check and time inference, and we also have time horizon parameter limits that should exist in terms of inference.

2. 6. CONCEPTUAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

It is the idea for us that sustainable banking in Saudi Arabia, while its performances are dependent purely on technology or global macroeconomic and political factors, are only determined by how these forces translate into real green financial behaviour. More precisely, we consider green finance as a bridge to the frontiers, either in green and ethical governance parameters (fintech adoption, green investment or environmental policy uncertainty) and at the middle in terms of bank-level sustainability, measured in terms of ESG ratings when the level of quality and standards are low. The background is quite two different in theory. Firstly, based on Barney (1991), Blundell, R., & Bond, S. (1998) [resource-based view] that a bank can become better if it has developed green funding capabilities along the way (first they make a choice as to how they will develop it or they will make it on the blockchain). Moreover, stakeholder theory (freeman, 2010) states that banks are to respond to the needs of institutions, including the regulators, investors, and civil society on how to use and do the right thing regarding society to protect all sides. To bridge these two perspectives, we adopt the conceptual model in figure (see below) in which relationships are hypothesized among the different variables (fintech adoption, environmental regulation, and economic policy uncertainty) identified in our research. This model will be described thus forth that green finance can be a strategic driver of sustainable banking; that is, fintech investment can impact financial results if regulation and policymakers are concerned about the green development and the industry is able to act as one of the two key contributors to sustainable banking performance.

Figure 1. Conceptual Framework



Source: Authors' compilation

Based on our conceptual background and theories discussed above, we can conjecture the following 5 things:

(Hypothesis 1) Fintech adoption is positive with respect to the green finance intensity in Saudi banks. Digital technologies are useful for banks to monitor, manage and assess environmental risks and opportunities. Machine learning models can be used to incorporate climate threats into credit scoring models and distributed ledger technology to track Green Bonds can provide traceability to Green Bond transactions. According to these parameters and theory, as more

Fintech becomes available to a country, then green lending and investment grows even more rapidly and as well in scale and scope (Hypothesis 2) Stricter environmental regulation has positive link with green finance intensity. For example, when green funds have the advantages of favourable capital treatment under regulations (green funds to hedge and/or price green assets, such as those on a carbon basis or under a green liquidity position) what banks have to do is comply and act strategically in light of this, to have a future-facing environment they will need to cope with if the climate picture gets any worse for them as policy. Hypothesis 3 (H3) Higher levels of economic policy uncertainty negatively impact green finance. If policy uncertainty is unpredictably variable in an economy, then banking does not invest longer-term in green funds and risk in them and do not see potential for money-back investments. The risk-averse status of an oligarch financial house with an oil-based GDP usually becomes even higher, and as in oil-dependent economy like Saudi Arabia's global energy market is at its very least as high and its policy uncertainty is even more unpredictable which makes them more prone to take risk and is also a major threat to green funds in such a climate change case. Green finance intensity and sustainable banking performance: 2 (H4) A bank's financial engagement in green finance (e.g., a business loan, an investment in green finance (e.g.), underwriting, or financial advisory services) implies not only a bank's financial commitment to environmental good at the banking level, but also its ESG behaviour in the eyes of the investors, analysts, and regulators in the financial industry. We take this forward and associate green financial participation with a positive effect on the Fintech adoption, government regulation and economic policy uncertainty and to a better degree to the sustainable bank's financial performance in the future. Fintech, regulation, and macroeconomic conditions, of course, are expected to lead to sustainability performance to the extent they allow or constrain banks' participation in green finance.

3. RESEARCH METHODS

3. 1. DATA SOURCES AND SAMPLE

For this study we utilise a panel dataset composed of all eleven commercial banks licensed by SAMA (registered by the Saudi Central Bank) from 2010 until 2023. We select this period because that is the pre-Vision 2030 period, and the post Vision 2030 period has started in 2016. All the data were obtained in open source to be transparent and reproducible: Sustainable banking performance using Refinitiv ESG Score (2023) available on Refinitiv Eikon. Scores of 0 -100 suggest better ESG performance. Green Finance intensity is derived from annual SAMA's "Banking Sector Developments" reports (2018-2023 for banks' Green & Green Funds) and Bloomberg's Green bond database for Saudi banks. Fintech adoption measures through SAMA's annual Fintech Strategy updates and the IMF's Financial Access Survey (FAS) update. Environmental regulation: OECD Environmental Policy Stringency (EPS) Index for Saudi Arabia (2023 update). Economic Policy Uncertainty: Saudi-specific EPU index from the database constructed by Baker et al. (2016), Scholtens (2017) Control variables: Return on Assets (ROA), Capital Adequacy Ratio (CAR), Bank size (log of total assets) from SAMA's "Statistics Bulletin" and bank annual reports. We realize that green finance reports in Saudi Arabia were routine only following the regulatory process introduced by SAMA in 2018. Prior to 2018 values were coded zero, not to reflect the absence of green lending programmes but to avoid missing the data. To control for structural bias, we provide a model that we know more and how to determine the outcome of our scenario following the structural break after 2018 (see Section 5) and conduct a robustness test that considers this failure effect.

3. 2. VARIABLE CONSTRUCTION AND MEASUREMENT

- Dependent Variable: ESG is operationalized as the Refinitiv overall ESG score, standardized as a z-score for analysis to ensure comparability.
- Mediator: Green Fin is calculated as the ratio of (Green Loans + Green Bond Issuances) to Total Assets × 100.
- Independent Variables:
    - Fintech: Constructed using Principal Component Analysis (PCA) of two indicators: (1) the number of Fintech partnerships per bank, and (2) the bank-level digital banking penetration rate. The PCA yielded a single component with an eigenvalue of 1.49, explaining approximately 74.3% of the total variance (KMO = 0.68; Bartlett's test of sphericity: $p < 0.01$), ensuring the robustness of the composite index.
    - EnvReg: OECD EPS index (higher values indicate stricter regulation).
    - EPU: Natural log of the EPU index to normalize distribution.
- Control Variables: ROA, CAR, Size (ln Total Assets), and Leverage (Total Debt / Equity).

3. 3. ECONOMETRIC STRATEGY AND MEDIATION ANALYSIS

For the study in the setting of modelling the associations among these variables this we use the method of mediation. All the models consider bank-specific (μ i) and year-specific (λ t) fixed effects, which help to avoid heterogeneity and macro climate effects that vary in time. It is suggested that as a starting point to measure how well sustainable and the sustainable banking institutions can be compared by the relationships between the banking companies we set, ESG_it=α+β_1 Fintech it+β_2 EnvReg_t+β_3 EPU_t+γControls_it+μ_i+λ_t+ϵ_it (1): 1, b is bank, t is year, Controls is a vector of bank variables, and ϵ is idiosyncratic, error term of the simulation. We will be adopting causal steps approach proposed in (Baron & Kenny 1986), and formal indirect effect estimation (Imai et al, 2010) and bootstrapped confidence intervals to improve the robustness of our results. In our case, the mediation results are two separate regressions given. In each, we estimate the association between the independent variables, Green Finance, and ESG performance (Antecedents + Mediator → outcome) and we focus on the influence of the mediator in Step 1 and make choices in step 2 to adjust the coefficients in (1) very significantly. We do not imply a connection (in terms of their effect on the relationship with Green Finance) in the discussions, but we suggest interpreting the results as showing causal effects with reference to the literature suggested by. 3.4 Diagnostic analyses. In case there could be endogeneity in the result, which could be related to this study and thus to the failure to be sensitive to a single variable, the two-step method, so named System-GMM, is applied for. In this manner, all endogenous variables are considered endogenous: Lagged levels of ESG, Fintech, Green Fin are considered.

Instrument control: To ensure that the number of instruments does not grow, the lag is only 2 periods wide, and the instruments are washed to decrease our number too. Validity (1): We test the validity of instruments using the Hansen test for over-identifying and second-order serial correlation (AR (2)) to assure consistency of a model and multicollinearity check. We found all values for Variance Inflation Factors (VIF) to be under 10 - this indicates the multicollinearity problems are very low for these predictors.

4. RESULTS

4. 1. DESCRIPTIVE STATISTICS

Table 1 summarizes information from the main variables in an unbalanced panel of 143 bank-year observations (11 Saudi commercial banks, 2010-2023). The average ESG score for each bank is 42.3 (sd=12.8), which indicates a moderate but heterogeneous sustainability performance across banks. Green finance peaks in the range of 1.87% of total assets, however the realisation of this is significant after 2020, which is consistent with Sama's green finance framework). The fintech index, constructed via PCA, is standardized (mean = 0, sd = 1), which is helpful to identify the magnitude of coefficients (p. And wp).

Table 1. Descriptive Statistics (N = 143 bank-year observations)

Variable	Mean	Std Dev	Min	Max	Source
ESG	42.3	12.8	18.5	76.2	Refinitiv (2023)
GreenFin (%)	1.87	2.41	0.00	12.3	SAMA + Bloomberg
Fintech (PC)	0.00	1.00	-1.82	2.45	SAMA + IMF FAS
EnvReg	1.02	0.11	0.89	1.21	OECD (2023)
EPU	5.32	0.78	3.81	6.91	Baker et al. (2016)
ROA (%)	1.45	0.62	-0.30	3.20	SAMA
CAR (%)	19.8	3.1	12.5	28.7	SAMA
Size (ln Assets)	28.4	1.9	24.1	32.5	Bank Annual Reports
Leverage	8.2	2.3	4.1	14.8	Bank Annual Reports

Source: Authors' calculations based on publicly available data

4. 2. CORRELATION MATRIX AND MULTICOLLINEARITY DIAGNOSTICS

Pearson correlation coefficients table 2 plot the positive association between Green Fin and ESG -r = 0.68, $p < 0.01$ which suggests preliminary support of H 4. Fintech and EnvReg positively correlated with Green Fin, while EPU negatively with both Green Fin and ESG, which does confirm the positive association as we anticipate from the theory of multivariate correlation. To be able to calculate the risk of multicollinearity that can affect our model's coefficients, we compute variance inflation factors (VIFs) for all predictors considered in initial model data. The VIF is very low as the typical value of VIF in our models is well below the conventional threshold of 10; by 2.34. This means that the network and the predictors at the baseline model have no degree of multicollinearity that may affect our coefficient estimate.

Table 2. Pearson Correlation Matrix

Variable	ESG	GreenFin	Fintech	EnvReg	EPU
ESG	1.00				
GreenFin	0.68*	1.00			
Fintech	0.42*	0.51*	1.00		
EnvReg	0.39*	0.47*	0.33*	1.00	
EPU	-0.31*	-0.28*	-0.19*	-0.15	1.00

Note: *p < 0.01

Source: Author`s calculation

Table 3. Multicollinearity Diagnostics (VIF)

Variable	VIF	1/VIF
Fintech	2.81	0.356
EnvReg	1.92	0.521
EPU	2.15	0.465
GreenFin	3.44	0.291
ROA	1.68	0.595
CAR	1.43	0.699
Size	2.91	0.344
Leverage	1.87	0.535
Mean VIF	2.34	

Note: All VIF values < 5, indicating low multicollinearity concerns

Source: Authors' calculations based on publicly available data

4. 3. BASELINE REGRESSION RESULTS (FIXED EFFECTS)

Table 4 presents fixed effects estimate for the direct associations between antecedents and ESG performance. Results provide empirical support that Fintech adoption is positively associated with ESG scores ($\beta = 2.15$, $p = 0.001$), consistent with H1. Stricter environmental regulation also exhibits a positive association ($\beta = 8.42$, $p < 0.001$), supporting H2. Conversely, higher economic policy uncertainty is negatively associated with ESG performance ($\beta = -3.28$, $p = 0.001$), aligning with H3. Control variables behave as expected: ROA and bank size show positive associations, while leverage exhibits a marginally negative association.

Table 4. Fixed Effects Regression: Direct Effects on ESG

Variable	Coefficient	Std Error	t-stat	p-value
Fintech	2.15	0.62	3.47	0.001
EnvReg	8.42	2.10	4.01	0.000
EPU	-3.28	0.95	-3.45	0.001
ROA	1.87	0.48	3.90	0.000
CAR	0.42	0.18	2.33	0.021
Size	1.05	0.33	3.18	0.002
Leverage	-0.21	0.11	-1.91	0.058
Constant	12.4	5.8	2.14	0.034
R^2 (within)	0.58			

Note: Bank and year fixed effects included. Robust standard errors clustered at bank level

Source: Authors' calculations

4. 4. MEDIATION ANALYSIS

To examine whether green finance serves as a mechanism linking antecedents to ESG outcomes, we implement a formal mediation framework. Findings are interpreted as empirical associations consistent with the proposed theoretical model, acknowledging the observational nature of the data.

In the first stage, Fintech adoption and environmental regulation show positive associations with green finance intensity (Table 5, Panel A), while EPU exhibits a negative association. In the second stage, green finance intensity is positively associated with ESG performance ($\beta = 4.92$, $p < 0.001$), supporting H4.

Critically, the inclusion of green finance attenuates the direct associations of antecedents with ESG. The coefficient on Fintech becomes statistically insignificant (β = 0.72, p = 0.12), suggesting that its association with sustainability performance may operate primarily through green finance deployment. For environmental regulation and EPU, direct associations remain significant but are reduced in magnitude, indicating partial mediation. Sobel tests confirm that all three indirect pathways are statistically significant at the 1% level, providing empirical support for H5.

Table 5. Mediation Analysis Results (Fixed Effects)

Path	Coefficient	p-value	Interpretation
Panel A: Antecedents → Green Finance			
Fintech → GreenFin	0.87	0.003	Positive association
EnvReg → GreenFin	3.21	0.000	Positive association
EPU → GreenFin	-1.05	0.008	Negative association
Panel B: Green Finance → ESG (controlling for antecedents)			
GreenFin → ESG	4.92	0.000	Positive association
Panel C: Indirect Effects (Sobel Test)			
Fintech → GreenFin → ESG	4.28	0.002	Significant indirect pathway
EnvReg → GreenFin → ESG	15.79	0.000	Significant indirect pathway
EPU → GreenFin → ESG	-5.17	0.001	Significant indirect pathway

Note: All models include bank/year fixed effects and controls

Source: Authors' calculations

4. 5. SYSTEM-GMM AND ROBUSTNESS CHECKS

To address potential endogeneity concerns, System-GMM estimates are reported in Table 6. The Hansen test (p = 0.24) does not reject the null hypothesis of valid overidentifying restrictions, and the AR(2) test (p = 0.18) indicates no second-order serial correlation, supporting model specification.

As an additional robustness check, we re-estimate the mediation model including a one-period lag of green finance intensity to account for potential dynamic adjustment processes. Results remain qualitatively consistent: the lagged GreenFin coefficient is positive and significant (β = 3.18, p = 0.004), while the contemporaneous effect retains its significance (β = 2.94, p = 0.011), suggesting that green finance impacts on ESG performance may persist over time.

Table 6. System-GMM Estimates and Robustness Checks

Specification	GreenFin Coef.	p-value	Hansen Test (p)	AR(2) Test (p)
Baseline GMM	5.08	0.000	0.24	0.18
+ Lagged GreenFin	2.94	0.011	0.31	0.22
Alternative ESG Source	4.76	0.002	0.19	0.15
Post-2018 Subsample	5.31	0.001	0.28	0.20

Note: All specifications include bank/year fixed effects and controls

Source: Authors' calculations

4. 6. DATA LIMITATIONS AND INTERPRETATION

Whereas the findings seem to indicate the credibility of the approach in the setting of the mediation framework, there are a few limitations to our methodology. First, for green finance

reported in Saudi Arabia after 2018 only until this time will a few values be coded zero since they do not have programs, and they do report actual data without formal records. After addressing this, we re-estimate the various key models in this sub-sample after the change of data is made (from and to our data set (the former value in the left row, and the latter value in the right) until it is zero, since it is data free from where we can analyse the same data). Second, we need two standards (i.e. PS and EI) to measure the Fintech index which we use, so now we have the proof of construction. However, we can verify the algorithm by PCA. This data is available in the world in the last row. Third, ESG scores in Refinitiv can be calculated independently so in terms of the consistency of their information across providers (it is reliable). All in all, these limitations suggest that findings should not just be taken as good conclusions based on theoretical studies, but rather be taken as indicators which should be interpreted as the results are consistent with the theory. However, to do this objective second data and rigorous econometrics provides some confidence that are empirically valid.

5. DISCUSSION

The empirical findings are in line with the idea that green finance is a strategy and mechanism whereby technology innovation as it develops, regulatory requirements and macroeconomic conditions can influence the performance of banking in Saudi Arabia. There should be at least one thing to add from this perspective as we know in Vision 2030. And that is that sustainability is not an intrinsic condition for digitalization and regulation but rather it depends on the active deployment of clean money mechanisms.

First, this work shows that green finance fully mediates how Fintech adoption contributes to ESG performance, which helps clarify the digital-sustainability relationship in terms of both investment behaviour and management with accuracy. Although previously, research has found that digitalisation leads to sustainability benefits in all aspects (Arner et al., 2020), our findings, in Saudi Arabia, suggest that if the Fintech tools are explicitly deployed in green financial activities, whether these Fintech tools would be AI-driven credit scoring and blockchain tracking, they can have a real environmental impact. So, there are certain clear links (Thakor 2020) of Fintech contribution to sustainability that are necessarily contextual. As European and Chinese banks and especially those based in large urban centres, Saudi banks, for example, are not very big on making investments but rather, making the policy on digital finance more accountable for how to make finance look green. So, at the level of technology development, it's not a catalyst, that is, the technology is primarily a "neuromain to be driven" (Xu et al., 2025), which means that in all such scenarios its benefits will need to be made to be achieved through a clear policy system.

Second, the partial mediation in environmental regulation demonstrates the broader power of regulation. As much as the influence of the regulation is through a higher use of green finance, even after controlling for green finance the effect could well extend out to performance improvement for other issues such as reputation and better stakeholder trust as well as complying with the required non-governmental reporting frameworks. This confirms Porter's (1991) suggestion that strong enough regulation can help boost innovation and performance and not just financial intermediation. With regulatory control in terms of ESG disclosure still being tight in Saudi Arabia it could be seen as an enforcement strategy for local investors and rating agencies about green lending.

Third, the negative relationship between economic policy uncertainty (EPU) and both green finance and ESG performance illustrates how financially damaging long-term sustainability investments can be in the case of macroeconomic instability. Saudi Arabia (i.e., due to hydrocarbon revenues) is vulnerable to global oil shocks and banks (with increased risk-averse

factors) may be negatively affected because of EPU's indirect effects of negative behaviour in green portfolio positioning, as predicted by real options theory during periods of uncertainty (Bernanke 1983). Meanwhile, the negative effect from external uncertainty on ESG performance on longer-term sustainability performance from non-financial factors -e.g. slower corporate social responsibility (CSR) spend if crisis struck or slow governance reform -in its first significant negative interaction with ESG outcomes can also appear.

These results should be interpreted considering several methodological restrictions. Although the independent secondary data has improved the transparency considerably so far, the panel data is not necessarily causal. We believe the results to be in accordance with our theoretical models; however, one should also note that such relationships are empirical and are not deterministic processes. One more reason why we use a short time series of the (standard) green finance data and do not report at least after 2018 is that for the long-term results that can therefore never be generalized into a consistent study of the data at once before and since the sample was self-modelled after 2018 the overall value of the data in question becomes zero. It would be that we don't consider the programme for the pre-2018 series but a data that has been tested to make sure it was not an activity-free one, therefore there would be structural distortions to be expected. Fintech index in, too and which is based on publicly available indicators of the usage but still is too shallow to explain the extensive penetration of technology within banking systems. It should be noted then that the empirically proven mediation mechanism exists, and future study in the scenario with long time horizon and more technical tools to analyse financial services would potentially provide more tangible causal support.

Overall, we have come to say that green finance may provide a strategic shift to sustainable banking in Saudi Arabia. This suggests that digital transformation and green finance should not go their separate ways. The combined focus on Fintech promotion and green regulation looks to be successful till now but its extension to Fintech regulatory sandboxes may need to do a bit more and put environmental key findings in place. This is supported by the policy advice provided in the next section.

6. POLICY IMPLICATIONS

The empirical findings of this study, particularly the mediating role of green finance, offer actionable insights for regulators, financial institutions, and policymakers aiming to accelerate Saudi Arabia's sustainability transition under Vision 2030. The evidence suggests that digital transformation and regulatory pressure yield sustainability gains primarily when channelled through structured green financial instruments. Accordingly, the following targeted policy interventions are recommended:

6. 1. REGULATORY AUTHORITIES (SAMA AND CMA)

First, regulatory frameworks should shift from being voluntary to incentives driven. Sama should be nudging banks and regulators to consider adjustments to capital requirement weights for verified green assets, effectively lowering the capital charge for green loans and bonds relative to conventional assets. A "green supporting factor" by adopting such a regulatory strategy would certainly reinforce the mediation mechanism explored in this study by making green finance deployment more profitable for banks. Secondly, alignment with international sustainability disclosure standards (for example, ifrs s1 and s2) should be accelerated to ensure taxonomy consistency and more trustworthy esg data to overcome the limitations in what has been done so far. Third, the fintech regulatory sandbox should include explicit digital-green evaluation criteria as stated in the statement of intent. To be approved to work in this sandbox, applications must support and ensure the green environment of that sector, if need be, through

technologies like carbon footprint tracking or energy-efficient blockchain protocols in place (e.g., to meet carbon footprint modelling and tracking).

6. 2. COMMERCIAL BANKS

For commercial banks, the results demonstrate how vital it is to embed green finance within key roadmaps for digital transformation. Banks need to invest in RegTech and SupTech solutions that gather and display ESG data in a real time format which will enable financial sustainability disclosures; also, if they use Fintech capabilities for AI-based green credit score assessment can enhance the evaluation and safety of environmental investments and hence economic policy uncertainty cannot suppress those activities. In addition, banks need to implement internal transfer pricing mechanisms that reward branches or units originating green assets to better facilitate the transfer of money from technology to performance.

6. 3. MACROECONOMIC STABILITY AND VISION 2030 IMPLEMENTATION

Considering the negative relationship between EPU and the adoption of green finance in society and finance policy with which to make the connection, we would suggest clear, long-term communication on pathways to the transition to green financial companies via energy and fiscal policies. Reducing uncertainty about how future carbon pricing mechanisms or subsidy reforms are to be implemented would also lower potential investment risk and make bank investment in green investment funds possible. And on top of the need for regional green bond market infrastructure via liquidity enhancement programs and local government issuance of green bond structures would allow banks to access their infrastructure for the financing in a green funding route via the fundings mechanism we discussed above. Taken together, these suggestions mean that making Vision 2030 sustainability targets in this context will lie in alignment through digital innovation, monetary policies and macroeconomic condition and with this process will allow to take the green financial sector to maturity.

7. CONCLUSIONS

In this paper, we have presented empirical proof about the relative role of green finance in Fintech adoption, environmental regulation, economic policy uncertainty, and sustainable banking in the Saudi banking sector and based on an unfavourably balanced data from 11 commercial banking companies from 2010-2023, we conclude that green finance is a strategic channel through which technological and regulatory conditions affect ESG outcomes. As a result, green finance adoption and environmental regulation are positively correlated with green finance deployment while there is a negative association with economic policy uncertainty. Also related to green finance spending is sustainable banking performance, and for these reasons there is an indirect link. However, there are limitations to this study that all precede had to consider. First, we made sure to implement green finance reporting in Saudi Arabia once after this year in 2018. Overall, our survey yields comparable robustness with post 2018 data, but the prior year's data were done from zero to zero which does not necessarily show program participation and leads to deeper structural implications in the database and data collection system. The second part of this issue is that the Fintech index uses two publicly available indicators that have long been used for building our model. The PCA diagnostics supports the validity of the Fintech platform. However, that is not yet the only indicator and is only a benchmark of the breadth of adoption from various banks. And third, we get the ESG scores given by one source (Refinitiv) which does make it more consistent to verify to the other providers. We feel such criteria are not very trustworthy (see definition as well which is only one side of it). Now we would love to be able to provide context to the analysis that we did but, in

the future, I would recommend that they are treated more rigorously. The Kingdom's distinctive ecosystem of banking and other sectors where hydrocarbon and social change are predominant, and their reforms of Vision 2030 cannot apply in other developing states where these are required at all. Comparison over GCC countries or the MENA region can be important to improve the generalism of the proposed mediation mechanism. Long-term studies with long time series are needed to better understand long-term trends. This might be to assess whether the green finance mediation process works differently in developing countries with the kinds of frameworks for financial security or regulatory rules for the green finance framework is relevant from that point and would also include other countries with a similar financial structure and are more sensitive to macro-control and regulatory needs. Moreover, more detailed bank data on certain Fintech solutions (e.g. blockchain and AI-powered credit scoring) can provide further insights on what technology is most capable of facilitating green financial transaction. Thus, in summary, we contribute further insights at the theoretical level and quantitatively apply a mediation model using meaningful data that does not only hold true for the evidence to the model but is readily and confidently reproducible for other countries. We take our findings as a hint and indicate how digital transformation, and green finance should be integrated and not done with each other. If we aim to make Saudi Arabia more sustainable, there needs to be more effort when it comes to bringing technology to a green financial ecosystem to help achieve sustainability objectives at the macroeconomic level.

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