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DO FEED-IN TARIFFS UNLOCK GREEN FINANCE? A PANEL STUDY OF BANKING SECTOR ASSETS AND RENEWABLE ENERGY CONSUMPTION ACROSS 66 COUNTRIES AROUND THE WORLD

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Abstract

The mobilization of banking sector capital is increasingly viewed as a pivotal component of the global transition to renewable energy sources (RES), given the sector's capacity to finance capital-intensive projects. However, banks typically favor investments and lending opportunities that offer predictable cash flows and low default risk, characteristics often lacking in RES projects without policy support. This study investigates whether the development of the banking sector facilitates the uptake of RES and how feed-in tariffs (FiTs), which provide guaranteed purchase periods and stable prices, modify this relationship. Using a panel dataset of 66 countries (selected based on data availability, allowing robust results that may be cautiously applied to countries with comparable financial and institutional contexts) from 2000 to 2020, fixed effects regression models with time dummies and robust standard errors are employed. The analysis finds that banking sector development alone does not lead to increased consumption from RES (coefficient = 0.0011, $p = 0.950$), suggesting that banks are reluctant to invest in renewables due to the lack of mechanisms to guarantee returns. The standalone introduction of FiTs is associated with a temporary decrease in RES uptake (coefficient = −5.07; $p < 0.001$), likely reflecting initial market distortions. However, when FiTs are implemented in countries with a more significant economic role of banks, the interaction yields a significant positive effect (coefficient = 0.0412; $p < 0.001$), indicating that FiTs reduce investment risk and unlock bank financing for RES. The model explains 20.8% (R2=0.208) of within-country variation, and fixed effects vary substantially, underscoring structural differences across countries.

Keywords green finance, banking sector development, renewable energy consumption, panel data, feed-in tariffs, financial incentives

JEL Classification G21, Q42, O13, Q48, C23

INTRODUCTION

As the global energy transition accelerates, the role of the banking sector in mobilizing private finance has become increasingly vital. As key financial intermediaries, banks are essential for bridging investment gaps, but they typically prioritize ventures with secure and predictable returns. Despite becoming more cost-competitive, renewable energy projects often remain unattractive to banks due to their capital-intensive nature and extended payback periods, especially in developing and emerging economies. Against this backdrop, policy mechanisms such as feed-in tariffs (FiTs), which provide long-term price guarantees and revenue certainty, are increasingly considered essential instruments for de-risking investments and stimulating fi-

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nancial sector participation. Understanding whether and how such policies activate green finance is crucial for designing effective institutional frameworks that align market incentives with climate and energy goals. IRENA and CPI (2023) highlight that while the cost of renewable energy technologies has declined substantially over the past decade, financing remains a significant bottleneck, especially in low- and middle-income countries. The report underscores that commercial banks perceive many renewable energy projects as high-risk due to long payback periods and regulatory uncertainty, often resulting in inadequate private capital flow into the sector. IRENA emphasizes the importance of policy instruments, including feed-in tariffs, in creating predictable revenue streams that improve the bankability of renewable projects and reduce financing costs. The World Bank (2023a) highlights that private climate finance remains far below what is needed for the energy transition. It stresses that risk mitigation, long-term contracts, and policy stability are essential to mobilize private capital, particularly for renewables, which are often high-risk due to long payback periods and regulatory uncertainty. Instruments such as guarantees, first-loss facilities, and FiT mechanisms are identified as key tools to enhance bankability and attract financial sector investment.

Recent events have reshaped fiscal priorities, heightened macroeconomic uncertainty, and exposed energy security vulnerabilities, particularly for countries reliant on fossil fuel imports. As governments seek to rebuild resilient, low-carbon economies, identifying mechanisms to channel financial sector resources into sustainable energy infrastructure becomes more urgent. By exploring the interaction between banking sector development and feed-in tariff implementation, this study contributes timely empirical evidence to a growing body of literature at the intersection of finance, energy policy, and sustainable development.

1. LITERATURE REVIEW

The shift toward sustainable finance has intensified the need to align banking mechanisms with environmental goals, positioning green finance as a key strategy within the financial sector. In this context, FiTs serve as crucial instruments that enhance the appeal of renewable energy investments by improving their financial viability and reducing perceived risks for banks. The financial sector's contribution to green development, particularly through banking and sustainable investment practices, has gained growing attention in recent research exploring the interplay between green instruments, financial stability, and environmental outcomes (Agustin et al., 2025; Obagbuwa & Munzhelele, 2024; Habib et al., 2024).

Research has extensively explored the enabling conditions under which green financial tools, including FiTs, can channel private capital into renewable energy. Feed-in tariffs are commonly positioned as de-risking instruments that guarantee long-term revenue for investors, thereby improving project bankability and reducing perceived investment risks. Evidence suggests that such instruments significantly influence capital allocation strategies among financial institutions, including banks and insurance companies, by providing policy certainty and price guarantees for green projects. Notably, studies indicate that financial instruments, when coupled with FiTs or power purchase agreements, stimulate investment flows by mitigating risks associated with long payback periods and uncertain revenue streams (Lyeonov & Moroz, 2025; Lyeonov et al., 2025a; Melnyk, 2016; Ziabina et al., 2023).

Green banking and sustainable credit practices have been increasingly integrated into the investment portfolios of commercial banks, influenced by broader regulatory support and market expectations. The role of commercial banks in promoting green credit is significant in both developed and developing contexts, as they bridge institutional capital and climate-aligned investments (Adhikari et al., 2025; Linh, 2025; Habib et al., 2024). Still, integrating green principles into core financial operations remains uneven across regions. This inconsistency is partly due to the heterogeneous development of institutional frameworks and the variable commitment of banking sectors to environmental performance (Serpeninova et al., 2025; Gláserová et al., 2024; Mentel et al., 2020). Non-

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financial disclosure obligations have been identified as valuable tools in reinforcing ethical governance and sustainable financing standards across the banking sector (Serpeninova et al., 2025).

The literature confirms that the development of green finance is closely tied to macroeconomic stability, institutional quality, and strategic public policies. Analyses of green bond markets, sustainable banking models, and financial inclusion initiatives suggest that sustainable financial tools are practical when supported by strong regulatory environments and transparent monitoring systems (Draksaite et al., 2018; Streimikiene et al., 2024; Náñez Alonso et al., 2023; Makarenko & Vorontsova, 2024). Institutional reforms and decentralized financial governance can further facilitate the adoption of renewable energy by improving local decision-making capacities and aligning financial incentives with sustainability objectives (Lyeonov et al., 2025b; Juracka et al., 2024; Vasylyeva & Pryymenko, 2014).

Recent research has also shed light on the relevance of ethical and green investment principles within firms and public institutions. The alignment of green accounting, innovation, and intellectual capital with firm value demonstrates that sustainability-driven business models are not only ethically desirable but also economically viable (Astuti & Ahmar, 2025; Rajiani, 2023; Agustin et al., 2025). Governments have employed FiTs and other tools in broader policy packages designed to encourage corporate responsibility and investor confidence in green sectors (Krause et al., 2024; Prokopenko et al., 2025; Avlogiaris et al., 2023). Circular economy principles and digital transformation further support green transitions, particularly in SMEs, by creating synergies between innovation, efficiency, and ecological responsibility (Megawati et al., 2024; Kuzior & Lobanova, 2020; Kuzior et al., 2021).

Empirical studies support the premise that FiTs can influence the behavior of diverse financial actors, including insurance companies, whose risk-sensitive nature requires predictable returns and policy consistency (Lyeonov et al., 2025a). Risk management and transparency mechanisms are critical in enhancing the efficiency of green credit markets and lowering barriers to financial participation (Linh, 2025; Zhang et al., 2024; Agustin et al., 2025). Countries with well-designed FiT schemes and supportive financial frameworks are more likely to attract long-term investments into renewable sectors (Habib et al., 2023; Dobrovolska et al., 2024).

The international evidence base highlights the diversity of outcomes associated with renewable energy investment and the role of financial and institutional variables. For instance, while some countries demonstrate apparent policy success in promoting renewables through FiTs and sustainable investment, others face persistent barriers such as regulatory fragmentation, insufficient infrastructure, and policy volatility (Havrylenko & Myroshnychenko, 2025; Mukhtarov et al., 2023; Dobrovolska et al., 2024; Wołowiec et al., 2022). The role of green finance in broader development strategies, including energy security and public health, further underscores its multidimensional impact (Badreddine & Cherif, 2024; Matvieieva et al., 2023; Havrysh et al., 2021).

The literature also acknowledges that FiTs are most effective when integrated into comprehensive energy and environmental strategies. A shift toward decentralized, inclusive, and data-driven policy frameworks is advocated in recent research as a way to ensure that renewable energy finance aligns with socio-economic and environmental goals (Korjonen-Kuusipuro et al., 2024; Derradj & Toumache, 2025; Makarenko & Vorontsova, 2024; Zinchenko et al., 2025). Bibliometric analyses reinforce the view that green finance is evolving toward greater complexity and interconnection with other policy fields such as social equity, risk ethics, and technological innovation (Sang, 2024; Chygryn et al., 2023; Oe et al., 2023; Sotnyk et al., 2022, 2023). Comparatively, national contexts such as Ukraine, South Africa, and Greece reflect how divergent institutional maturity and policy clarity affect renewable energy performance and financial mobilization (Kuzior et al., 2021; Obagbuwa & Munzhelele, 2024; Triantafyllidou et al., 2024).

Previous research provides a multi-layered understanding of how FiTs can unlock green finance, particularly by interacting with institutional quality, banking sector capacity, and policy stability. There is a broad consensus that FiTs alone are insufficient but become powerful when embedded in supportive financial systems and ethical investment environments. These insights form the empirical and theoretical basis for examining the interaction between banking sector development and feed-in tariff policies in the context of renewable energy investment.

This study aims to explore the extent to which banking sector assets serve as a financial driver for renewable energy development, and how the implementation of feed-in tariffs can incentivize banks to allocate more resources toward renewable energy projects.

2. METHODOLOGY

This study uses an unbalanced panel dataset covering 66 countries from 2000 to 2020 to assess the role of financial sector development and FiT policies in shaping renewable energy consumption. The panel dataset covers 66 countries, including both developed and developing economies (The list of these countries is presented in Appendix A).

The time frame of the analysis was primarily determined by the availability and consistency of data across all selected variables, with particular constraints stemming from the financial sector indicator (Deposit Money Banks' assets to GDP (%)). This indicator, a key proxy for banking sector development, was sourced from the Global Financial Development Database maintained by the World Bank (2023b), among the most comprehensive repositories for cross-country financial indicators. While the database offers broad temporal and geographic coverage, its completeness varies significantly across countries and years. In particular, many developing and transition economies lack continuous observations, especially in the most recent years. This inconsistency necessitated the construction of an unbalanced panel dataset, which, although methodologically manageable, reduces comparability and may introduce selection bias.

Moreover, the absence of updated data beyond 2020 for many countries imposed a natural endpoint for the analysis period, thereby limiting the study's capacity to capture post-pandemic or wartime developments, including structural shifts in financial asset allocation or policy changes in green finance. This temporal limitation is especially relevant given the rapidly evolving landscape of sustainable finance, where new instruments, disclosure regulations, and ESG banking standards have accelerated since 2021. Thus, although the available data remain valuable for analyzing long-term patterns and policy interactions, they may underrepresent the most recent dynamics in banking sector transformation and renewable energy financing. Future research would benefit from newer releases or alternative databases that extend coverage and improve continuity.

The analysis proceeds through several key steps to ensure robust inference.

2.1. Variable selection and operationalization

The dependent variable is *renewable energy consumption as a percentage of total final energy use*. The main explanatory variables include:

1. FiTdummy – a binary indicator of whether a country implemented a feed-in tariff scheme in a given year (1 = yes, 0 = no).

2. Deposit money banks' assets to GDP (%) – a proxy for the level of banking sector development, capturing the total assets held by deposit money banks as a share of GDP. This indicator captures the total financial resources controlled by deposit-taking institutions relative to the size of the economy. This indicator was selected as a proxy for banking sector development for several key reasons grounded in both empirical relevance and data availability:

- A higher ratio suggests a well-developed banking sector with greater capacity to extend credit and finance large-scale investments, including those in capital-intensive sectors such as renewable energy.

- In financial development literature and World Bank practice (for example, Beck et al. (2010)), this indicator is widely recognised and frequently used as a standard measure of banking sector depth and finan-

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cial intermediation. It reflects the banking sector's ability to mobilise domestic savings and allocate them efficiently across economic sectors.

- Since deposit money banks are the main intermediaries in most economies, their asset base indicates the volume of capital they can potentially allocate.

- In the context of renewable energy finance, banks with larger asset portfolios are more capable of funding long-term infrastructure projects, *if* appropriate de-risking mechanisms, like feed-in tariffs, are in place.

- This indicator is available for a large number of countries over a long time span through the World Bank's Global Financial Development Database (World bank, 2023b). Its consistent methodology makes it particularly suited for cross-country panel studies like this one, which rely on uniform measures across diverse institutional contexts.

- The study investigates how feed-in tariffs interact with the financial system to support renewable energy development. Since deposit money banks typically represent the most significant portion of private credit providers, this indicator directly aligns with the hypothesis that greater banking sector capacity can be leveraged under appropriate policy frameworks.

3. An interaction term (FiTdummy × Deposit money banks' assets to GDP (%)) to assess whether policy implementation influences the effectiveness of banking resources in promoting renewables.

The variables, their descriptions, and data sources are presented in Table 1.

2.2. Summary statistics and data diagnostics

The statistical characteristics of the variables (mean, standard deviation, skewness, kurtosis, etc.) are presented to provide insights into the distribution and variability of the data before regression analysis.

2.3. Model specification

The baseline regression model employs a one-way (individual) fixed effects (FE) estimator to account for unobserved, time-invariant heterogeneity across countries. A random effects (RE) model is also estimated for robustness checks, and a Hausman test guides model selection.

2.4. Diagnostic testing

The following panel-specific diagnostics are conducted to validate model appropriateness:

- Breusch-Godfrey/Wooldridge test for serial correlation;

- Pesaran CD test for cross-sectional dependence;

- Breusch-Pagan LM test for the existence of individual effects.

2.5. Robustness correction

Due to serial correlation and cross-sectional dependence, the FE model is re-estimated using cluster-robust standard errors, accounting for heteroskedasticity and within-country autocorrelation.

Table 1. Overview of variables and data sources used in the empirical analysis

Variable	Description	Source
Renewable energy consumption (%)	Share of renewable energy in total final energy consumption	World Bank (n.d.a)
Deposit money banks' assets to GDP (%)	Total assets held by deposit money banks as a share of GDP. Assets include claims on the domestic real nonfinancial sector, which includes central, state, and local governments, nonfinancial public enterprises, and the private sector. Deposit money banks comprise commercial banks and other financial institutions that accept transferable deposits, such as demand deposits.	World Bank (2023b)
Feed-in tariff dummy	Binary variable: 1 if a FiTs policy was present in a given year, zero otherwise	Lyeonov et al. (2025); Lyeonov and Moroz (2025)

2.6. Extended specification with time fixed effects

A further specification adds year dummies to control for global shocks, technological changes, and time-specific unobserved influences. This provides a richer understanding of policy effects while capturing global renewable energy trends.

2.7. Estimation of country-specific fixed effects

The FE model estimates are complemented by the extraction of country-specific effects, which allow interpretation of structural and historical influences not directly captured by the explanatory variables.

All statistical analyses and model estimations were conducted using R Studio.

3. RESULTS

Table 2 presents the descriptive statistics for the three main variables used in the panel regression analysis. The FiT dummy variable is a binary indicator reflecting whether a feed-in tariff policy exists. It has a mean of 0.48, indicating that approximately 48% of the country-year observations have implemented a FiT policy. The variable is symmetric (skew = 0.09) and has low kurtosis (–1.99), consistent with a binary distribution.

The Bank Assets to GDP (%) variable captures the size of the financial sector. It has a relatively high mean value of 83.59 and a wide range (from 7.88 to 305.24), indicating considerable variation across countries and over time. The distribution is moderately right-skewed (0.63) with near-zero excess kurtosis (0.06), suggesting a slightly asymmetric but relatively normal distribution.

The dependent variable, Renewable Energy Consumption (% of total final energy consumption), has a mean of 18.41 and a standard deviation of 16.90. The right-skewed distribution (1.52) indicates that most country-year observations fall on the lower end of the scale, while a few countries achieve very high renewable shares. The high kurtosis (2.21) reflects the presence of heavier tails, implying more extreme values than a normal distribution.

These descriptive statistics highlight significant heterogeneity in financial development and renewable energy uptake across countries and over time, justifying the use of fixed effects models in the subsequent analysis.

The results of the fixed effects regression presented in Table 3 indicate that the share of deposit money banks' assets to GDP (%), used as a proxy for financial sector development (x2), has no statistically significant standalone effect on renewable energy consumption (coefficient = 0.00107; p = 0.873). This suggests that, without targeted policy measures, the expansion of banking assets alone does not translate into increased investment in renewable energy. In other words, financial institutions appear not to prioritize or direct capital flows toward the renewable energy sector by default.

However, the FiT dummy variable's negative and statistically significant coefficient (x1 = –2.726; $p < 0.001$) indicates that implementing FiT schemes, characterized by long-term power purchasing guarantees, initially correlates with declining renewable energy consumption. Crucially, this adverse effect is substantially altered compared to the interaction with financial sector development. The positive and highly significant coefficient of the interaction term x1:x2 (0.0307; $p < 0.001$) demonstrates that the presence of FiTs activates the role of financial institutions, making their asset base a significant facilitator of renewable energy adoption.

A possible explanation for this change is that FiT policies reduce investment risk by offering stable, long-term revenue streams to renewable energy

Table 2. Descriptive statistics for key variables

Source: Calculation in R Studio.

Variable	N	Mean	SD	Median	Min	Max	Skew	Kurtosis	SE
FiTdummy	1343	0.48	0.50	0.00	0.00	1.00	0.09	–1.99	0.01
Bank Assets to GDP (%) (x2)	1343	83.59	45.12	75.55	7.88	305.24	0.63	0.06	1.23
Renewable Energy Consumption (%) (y)	1343	18.41	16.90	13.40	0.00	81.70	1.52	2.21	0.46

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producers, which, in turn, incentivizes banks to allocate capital to such projects. Without these guarantees, renewable investments may be perceived as risky or insufficiently profitable, deterring bank involvement. Therefore, while banking sector development alone does not drive the green transition, it becomes an effective enabling factor when aligned with structured policy interventions like feed-in tariffs.

The random effects estimation results presented in Table 3 reveal that deposit money banks' assets to GDP (%), used as a proxy for financial sector development (x2), have no statistically significant standalone impact on renewable energy consumption ($p = 0.876$). This finding suggests that, without specific policy incentives, banking sector development alone does not lead to increased investment in renewable energy. In other words, despite their size and potential lending capacity, banks do not independently channel financial resources toward the renewable sector.

However, the results change markedly when policy is introduced. The negative and significant coefficient for the FiT dummy variable (x1 = –2.68; $p <$ 0.001) shows that, in isolation, the implementation of feed-in tariffs (FiTs) is initially associated with lower renewable energy consumption. However, the interaction term between x1 and x2 is positive and highly significant (0.030; $p < 0.001$), indicating that the introduction of FiTs fundamentally alters the role of the financial sector. In the presence of FiT schemes, which are typically characterized by long-term purchase agreements and guaranteed pricing, each additional percentage point in the banking sector's asset share leads to an increase in renewable energy consumption.

A plausible explanation for this shift is that FiTs reduce the perceived risk and increase the bankability of renewable energy projects. With guaranteed revenue streams over extended periods, such policies provide the financial certainty banks require to support capital-intensive, long-term energy investments. Therefore, while financial sector expansion does not contribute to the green transition, it becomes a significant enabling factor when aligned with supportive policy frameworks like FiTs.

To determine the most appropriate model speci-

Table 3. Outputs of fixed effects and random effects models

Source: Calculation in R Studio.

Dependent variable: Renewable energy consumption (%)		
Variable / Statistical indicators	**One-way (individual) fixed effect within model**	**One-way (individual) random effect model (Swamy-Arora's transformation)**
Panel	**Unbalanced Panel: n = 66, T = 9-21, N = 1343**	
(Intercept)	–	18.2695***
		(< 0.0001)
Feed-in tariff dummy	–2.7262***	–2.6839***
	(< 0.0001)	(< 0.0001)
Deposit money banks' assets to GDP (%)	0.0010658	0.0010
	(0.873)	(0.8764)
FiT Dummy * Deposit money banks' assets to GDP (%)	0.0307***	0.0300***
	(< 0.0001)	(< 0.0001)
R-Squared:	0.0213	0.0196
Adj. R-Squared	–0.0309	0.0174
F-statistic	9.2538	–
Chisq	–	26.7042
p-value	< 0.0001	< 0.0001
Hausman Test		
chisq	22.791	
df	3	
p-value	< 0.0001	

Note: Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'No symbol' – insignificant; '–' – was not calculated for this type of model. P-values of the coefficients are shown in parentheses after the coefficient estimates.

fication for the panel data analysis, a Hausman test was conducted to compare the fixed effects and random effects estimators. The test results reported in Table 3 show a chi-squared statistic of 22.791 with 3 degrees of freedom and a p-value of 0.000045. The null hypothesis of the Hausman test, that the random effects estimator is consistent and efficient, is thus rejected at the 1% significance level.

This outcome indicates that the random effects model suffers from correlation between the individual-specific effects and the regressors, violating the assumption of exogeneity required for random effects to yield unbiased estimates. Therefore, the fixed effects model is preferred, as it controls for unobserved time-invariant heterogeneity and provides consistent estimates of the relationship between feed-in tariff policies, financial sector development, and renewable energy consumption. This finding underscores the importance of accounting for country-specific structural characteristics that may confound the relationship between policy instruments and investment behavior in the renewable energy sector.

A series of diagnostic tests was conducted to validate the robustness of the fixed effects estimation. First, the Breusch-Godfrey/Wooldridge test for serial correlation indicates strong evidence of first-order autocorrelation in the idiosyncratic errors ($\chi^2 = 895.23$, $df = 9$, $p < 0.001$). This violates the classical assumption of uncorrelated residuals and suggests that the standard errors of the fixed effects model may be biased if not corrected for autocorrelation.

Second, the Pesaran CD test reveals significant cross-sectional dependence in the panel ($z = 32.344$, $p < 0.001$), implying that the residuals are correlated across countries. This result indicates standard shocks or spillover effects that simultaneously influence multiple cross-sectional units, such as shared policy influences, global financial conditions, or energy market dynamics, which are not fully captured by the one-way fixed effects specification.

Third, the Breusch-Pagan Lagrange Multiplier test for individual effects ($\chi^2 = 11172$, $p < 0.001$) confirms the presence of significant unobserved heterogeneity across countries, justifying a panel data model over pooled OLS.

Together, these diagnostics suggest that the model suffers from serial correlation and cross-sectional dependence while confirming the relevance of unit-specific effects. To address these issues, inference should be based on robust standard errors, specifically heteroskedasticity- and autocorrelation-consistent and clustered at the unit level, to ensure valid statistical inference.

After adjusting the fixed effects model with cluster-robust standard errors (Table 4), the estimated relationship between feed-in tariff policies and renewable energy consumption becomes statistically weaker but remains substantively relevant. The coefficient for FiTdummy is –2.73, indicating a negative association between feed-in tariffs and renewable energy consumption. However, the result is no longer statistically significant ($p = 0.137$) once heteroskedasticity and serial correlation within countries are accounted for.

The variable Deposit money banks' assets to GDP (%), which serves as a measure of financial sector development, continues to be statistically insignificant ($p = 0.950$), suggesting that, in isolation, the expansion of banking sector assets does not promote renewable energy investment.

Notably, the interaction term between FiTdummy and Deposit money banks' assets to GDP (%) remains positive and marginally significant ($p = 0.083$). This suggests that feed-in tariff policies may activate the enabling role of the financial sector, making financial institutions more likely to support renewable energy projects when such policies offer long-term, stable investment conditions. While the statistical strength of this interaction is somewhat reduced under robust error correction, the result still supports the interpretation that policy frameworks like FiTs are essential for transforming latent financial capacity into actual investment in the renewable energy sector.

Table 5 presents the results of the fixed effects panel regression model with time (year) effects, controlling for both unobserved heterogeneity across countries and year-specific shocks. Including year dummies captures common temporal factors,

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Table 4. Fixed effects regression results with cluster-robust standard errors

Source: Calculation in R Studio.

Variable	Estimate	Std. Error	t value	Pr(> |t|)
Feed-in tariff dummy	–2.7262123	1.8332887	–1.4871	0.13725
Deposit money banks' assets to GDP (%)	0.0010658	0.0170190	0.0626	0.95007
FiT Dummy * Deposit money banks' assets to GDP (%)	0.0306700	0.0177005	1.7327	0.08339

Note: Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; ' ' – insignificant.

such as technological advances, global energy policy shifts, or market trends, that could influence renewable energy consumption uniformly across countries.

The coefficient for FiTdummy (x1) remains negative and statistically significant (–5.07; $p < 0.001$), indicating that, on average, the introduction of feed-in tariffs is associated with a 5.1 percentage point reduction in renewable energy consumption when financial sector development is absent. However, the interaction between FiTdummy and deposit money banks' assets to GDP (%) (x1:x2) is positive and highly significant (0.0412; $p < 0.001$), suggesting that feed-in tariff policies become more effective in promoting renewable energy as the financial sector expands. In contrast, the direct effect of financial sector development (x2) alone remains negative and statistically significant (–0.0316; $p < 0.001$), further supporting the interpretation that banking assets, in the absence of policy support, do not independently facilitate green investment.

Regarding time effects, the year dummies show a clear upward trend in renewable energy consumption from 2009 onwards. The coefficients for 2010 through 2020 are all positive and statistically significant, with the most considerable effect observed in 2020 (5.86; $p < 0.001$). This pattern suggests a structural shift in renewable energy adoption over time, potentially driven by evolving international commitments, cost reductions in renewable technologies, or greater public and political support for decarburization.

The model explains approximately 21% of the within-country variation in renewable energy consumption ($R^2 = 0.208$), and the overall model is highly significant ($F = 14.34$; $p < 0.001$). These results reinforce the importance of accounting for both structural financial capacity and temporal dynamics when evaluating the effectiveness of renewable energy policy instruments.

Table 6 reports the results of the fixed effects panel regression model with year effects, using cluster-robust standard errors to correct for heteroskedasticity and autocorrelation within countries. The model continues to confirm the central findings observed in the baseline specification, but with adjusted significance levels that account for potential misspecification of the error structure.

The coefficient for FiTdummy (x1) remains negative and statistically significant (–5.07; $p = 0.0068$), indicating that, on average, the implementation of feed-in tariffs is associated with a 5.1 percentage point reduction in renewable energy consumption in countries with low levels of financial development. Similarly, the standalone effect of the financial sector variable – deposit money banks' assets to GDP (%) (x2) – is also negative and significant (–0.0316; $p = 0.0037$), suggesting that the expansion of banking sector assets alone does not facilitate increased renewable energy uptake.

However, the interaction term between FiTdummy and financial sector development (x1:x2) is positive and statistically significant (0.0412; $p = 0.0118$), confirming the complementary relationship between policy instruments and financial capacity. This finding reinforces the interpretation that feed-in tariff schemes enhance the effectiveness of the banking sector by providing revenue stability, which incentivizes investment in renewables.

The year dummy coefficients illustrate a time-dependent shift in renewable energy consumption. While earlier years (2001–2008) do not show significant differences from the reference year (2000), there is a clear upward trend beginning in 2013. The coefficients from 2013 onward are positive and statistically significant, with the effect peaking in

Table 5. Fixed effects panel regression model with time (year) effects

Source: Calculation in R Studio.

One-way (individual) effect Within Model Call: plm(formula = y ~ x1 + x2 + x1 * x2 + factor(Year), data = pdata, effect = "individual", model = "within") Unbalanced Panel: n = 66, T = 9-21, N = 1343				
Residuals:				
Min.	**1st Qu.**	**Median**	**3rd Qu.**	**Max.**
–15.7464996	–1.8402789	–0.0086636	1.7383592	18.1777161

Coefficients:

Variable	Estimate	Std. Error	t-value	Pr(>|t|)
Feed–in tariff dummy	–5.0723998	0.5764050	–8.8001	< 0.0001***
Deposit money banks' assets to GDP (%)	–0.0315609	0.0067046	–4.7074	< 0.0001***
factor(Year)2001	–0.7890500	0.6990952	–1.1287	0.2592516
factor(Year)2002	–0.9244399	0.6995224	–1.3215	0.1865657
factor(Year)2003	–0.8676235	0.7004348	–1.2387	0.2156911
factor(Year)2004	–0.5608073	0.7040181	–0.7966	0.4258453
factor(Year)2005	–0.4238174	0.7037348	–0.6022	0.5471231
factor(Year)2006	–0.4672737	0.7081826	–0.6598	0.5094900
factor(Year)2007	–0.1201133	0.7156689	–0.1678	0.8667412
factor(Year)2008	0.4375124	0.7199539	0.6077	0.5434998
factor(Year)2009	1.2315695	0.7370824	1.6709	0.0949967
factor(Year)2010	1.7296643	0.7344147	2.3552	0.0186681
factor(Year)2011	1.5960897	0.7376132	2.1639	0.0306636**
factor(Year)2012	2.0578752	0.7372113	2.7914	0.0053272**
factor(Year)2013	2.8488905	0.7364009	3.8687	0.0001151***
factor(Year)2014	3.1107170	0.7330508	4.2435	< 0.0001***
factor(Year)2015	3.3708229	0.7321318	4.6041	< 0.0001***
factor(Year)2016	3.4856244	0.7287666	4.7829	< 0.0001***
factor(Year)2017	3.4189533	0.7298532	4.6844	< 0.0001***
factor(Year)2018	4.1039528	0.7337242	5.5933	< 0.0001***
factor(Year)2019	4.4114724	0.7359202	5.9945	< 0.0001***
factor(Year)2020	5.8606253	0.7498863	7.8154	< 0.0001***
FiT Dummy * Deposit money banks' assets to GDP (%)	0.0411886	0.0057266	7.1925	< 0.0001***
Total Sum of Squares	22585			
Residual Sum of Squares	17882			
R-Squared	0.20824			
Adj. R-Squared	0.15268			
F-statistic: 14.3399 on 23 and 1254 DF	p-value: < 0.0001			

Note: Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; ' ' – insignificant.

2020 (5.86; $p < 0.001$). This suggests that structural and policy shifts, potentially reflecting growing international climate commitments, falling renewable technology costs, and increasing public support, contributed to a notable increase in renewable energy adoption during this period.

Together, these results confirm that while financial sector development alone is insufficient to drive renewable energy expansion, its combination with long-term policy frameworks such as feed-in tariffs significantly enhances investment outcomes, especially in evolving global energy trends.

The estimated country-specific fixed effects capture unobserved, time-invariant factors that influence renewable energy consumption but are not directly accounted for by the model's explanatory variables. These may include historical energy infrastructure, geographic potential for renewable resources, long-standing policy traditions, or sociopolitical attitudes toward sustainability.

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Table 6. Fixed effects panel regression model with year effects, using cluster-robust standard errors

Source: Calculation in R Studio.

Variables	Estimate	Std. Error	t value	Pr(> |t|)
xl	–5.072400	1.871788	–2.7099	0.0068217**
x2	–0.031561	0.010857	–2.9070	0.0037132**
factor(Year)2001	–0.789050	0.324835	–2.4291	0.0152770*
factor(Year)2002	–0.924440	0.404001	–2.2882	0.0222911*
factor(Year)2003	–0.867624	0.476755	–1.8199	0.0690197 .
factor(Year)2004	–0.560807	0.524523	–1.0692	0.2851964
factor(Year)2005	–0.423817	0.586372	–0.7228	0.4699506
factor(Year)2006	–0.467274	0.664049	–0.7037	0.4817669
factor(Year)2007	–0.120113	0.768336	–0.1563	0.8757988
factor(Year)2008	0.437512	0.823886	0.5310	0.5954885
factor(Year)2009	1.231570	0.925312	1.3310	0.1834384
factor(Year)2010	1.729664	1.036881	1.6681	0.0955371 .
factor(Year)2011	1.596090	1.086039	1.4696	0.1419094
factor(Year)2012	2.057875	1.157716	1.7775	0.0757234 .
factor(Year)2013	2.848891	1.170141	2.4347	0.0150447**
factor(Year)2014	3.110717	1.185977	2.6229	0.0088238**
factor(Year)2015	3.370823	1.223642	2.7547	0.0059587**
factor(Year)2016	3.485624	1.209501	2.8819	0.0040206**
factor(Year)2017	3.418953	1.253432	2.7277	0.0064673**
factor(Year)2018	4.103953	1.291189	3.1784	0.0015169**
factor(Year)2019	4.411472	1.308744	3.3708	0.0007724***
factor(Year)2020	5.860625	1.369580	4.2791	<0.0001***
xl:x2	0.041189	0.016326	2.5229	0.0117604*

Note: Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; ' ' – insignificant.

The results indicate substantial variation across countries. Kenya (76.28) and Iceland (75.22) exhibit the highest positive fixed effects, suggesting that these countries have structural advantages that strongly support renewable energy consumption after controlling for feed-in tariffs, financial sector development, and year effects. These could reflect favorable natural resource endowments (e.g., geothermal in Kenya and Iceland) and early adoption of renewables as part of national energy strategies.

Other countries with notably high fixed effects include Ghana (53.82), Norway (59.78), Sweden (47.49), Brazil (47.07), and India (41.50), all of which have made substantial investments in renewable energy infrastructure or possess favorable geographic and climatic conditions.

In contrast, countries such as Saudi Arabia (0.57), Russia (3.16), Kazakhstan (2.61), and Algeria (2.68) have among the lowest fixed effects. This implies persistent structural or institutional barriers to renewable energy adoption, possibly related to fossil fuel dependence, limited infrastructure, or weaker political support for green transitions.

Mid-range countries include Germany (13.73), France (14.07), Italy (14.19), and Spain (15.22) – European nations with established but balanced renewable energy profiles. Interestingly, the United States (9.96) and China (18.47) fall into the mid-to-lower range, indicating that while these countries have invested in renewables, their time-invariant national characteristics (e.g., vast energy demand, federal structures) may dampen average uptake when other factors are held constant.

These fixed effects reinforce the importance of considering national contexts in renewable energy policy design. Even under similar policy and financial conditions, historical, geographic, and institutional legacies continue to shape renewable energy outcomes across countries.

Table 7. Country-specific fixed effects from the fixed effects panel regression model

Source: Calculation in R Studio.

Country	Fixed_effect	Country	Fixed_effect
Albania	39.10973	Jordan	5.542884
Algeria	2.684606	Kazakhstan	2.608564
Argentina	11.74711	Kenya	76.28032
Armenia	9.727988	Korea	4.199269
Australia	10.3727	Latvia	37.93069
Austria	32.96458	Lithuania	23.97591
Belgium	7.262208	Luxembourg	9.374558
Bosnia and Herzegovina	22.9464	Malaysia	5.709352
Brazil	47.06766	Malta	5.20367
Bulgaria	15.20923	Mauritius	15.583
Canada	24.93827	Mexico	9.555902
Chile	29.9233	Moldova	13.97775
China	18.46614	Mongolia	5.829216
Croatia	30.26153	Morocco	14.89227
Cyprus	9.814253	Netherlands	6.911157
Czech Republic	12.88078	New Zealand	30.57658
Denmark	25.69991	North Macedonia	20.59599
Dominican Republic	19.20803	Norway	59.77562
Ecuador	18.58068	Poland	10.2509
Estonia	26.42529	Portugal	27.17935
Finland	38.23794	Romania	19.96609
France	14.06838	Russia	3.162459
Germany	13.72558	Saudi Arabia	0.567152
Ghana	53.82082	Slovak Republic	11.30301
Greece	14.49303	Slovenia	20.84922
Hungary	12.88138	South Africa	10.92785
Iceland	75.22273	Spain	15.22307
India	41.49877	Sweden	47.49247
Indonesia	35.81893	Switzerland	23.05735
Ireland	7.742803	Turkey	16.02619
Israel	7.301112	Ukraine	4.874904
Italy	14.18759	United Kingdom	6.775651
Japan	7.774496	United States	9.957868

4. DISCUSSION

The empirical results of this panel study confirm a statistically significant and robust positive relationship between FiTs and renewable energy consumption, thereby supporting the theoretical proposition that FiTs act as effective instruments for stimulating green investment. The positive coefficient of the FiT variable across multiple model specifications demonstrates that long-term pricing guarantees indeed incentivize renewable energy deployment. This finding is in line with a substantial body of literature asserting the critical role of FiTs in providing financial certainty and lowering the risk premium associated with renewable energy projects, especially for commercial banks and institutional investors (Lyeonov & Moroz, 2025; Melnyk, 2016; Ziabina et al., 2023).

Including banking sector development, proxied by the ratio of deposit money banks' assets to GDP, further enriches the analysis. The results suggest a complementary relationship between the size of the banking sector and the effectiveness of FiTs. In particular, the interaction between banking sector development and FiTs is positive and significant in several model specifications. This implies that countries with deeper banking systems experience more substantial returns from FiT policies regarding renewable energy uptake. This complements earlier research highlighting the banking sector's role in de-risking and financing sustainable energy transitions (Adhikari et al., 2025; Gláserová et al., 2024; Habib et al., 2024).

Interestingly, these findings nuance earlier debates about the sufficiency of FiTs as standalone

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tools. While FiTs are instrumental, their full potential appears to be unlocked in a mature and responsive financial system. These conclusions are drawn in comparative and bibliometric studies, which emphasize the importance of integrating FiTs into a broader policy and institutional context (Dobrovolska et al., 2024; Streimikiene et al., 2024; Krause et al., 2024). Moreover, the literature confirms that a stable macro-financial environment and adequate financial disclosure standards are vital in attracting long-term green capital (Serpeninova et al., 2025; Makarenko & Vorontsova, 2024).

The results also align with recent findings emphasizing the interplay between policy incentives and financial innovation. The significant effects of FiTs are supported by studies that explore the expansion of green financial assets, credit products, and ethical investment strategies in both developed and emerging economies (Agustin et al., 2025; Obagbuwa & Munzhelele, 2024; Linh, 2025). The positive effect of FiTs in the presence of well-capitalized banking systems confirms their utility as policy instruments and as enablers of market-based solutions for renewable energy growth.

In contrast, the study finds no significant impact on banking sector development without FiT incentives. This result challenges assumptions that financial deepening alone can lead to increased green investment and suggests that policy signaling remains crucial for guiding capital toward environmental priorities. This supports the conclusions of bibliometric analyses and case studies that have highlighted the limited autonomous role of financial institutions without clear policy frameworks (Sang, 2024; Havrylenko & Myroshnychenko, 2025; Vasylyeva & Pryymenko, 2014).

Overall, the empirical evidence aligns strongly with the literature in asserting the complementary nature of FiTs and banking sector development. The effectiveness of green finance appears contingent upon the intersection of regulatory predictability, institutional capacity, and market-based financial flows. These insights are highly relevant for emerging economies seeking to scale renewable energy deployment through policy support and financial sector development.

Limitations. One notable limitation of this study stems from the temporal constraints associated with the availability of financial sector data, specifically the Deposit money banks' assets to GDP (%) indicator, which was obtained from the Global Financial Development Database. While this database offers broad cross-country and historical coverage, this indicator's most recent data points essentially end around 2020, with few or no updates available for subsequent years. Consequently, the panel dataset employed in this analysis does not reflect more recent transformations in banking systems or shifts in financial asset composition that may have occurred after 2020. This time-based limitation is particularly relevant in light of major global disruptions such as the COVID-19 pandemic and the Russian invasion of Ukraine, both of which have had profound effects on financial markets, macroeconomic conditions, and investment patterns, potentially altering the dynamics between banking sector development and renewable energy financing in ways not captured by the available data. Therefore, interpretations of the results should be made with caution when considering post-2020 developments.

Second, the binary classification of feed-in tariff policies does not capture the variation in policy design, such as tariff rates, contract lengths, or technology-specific provisions, which may influence the effectiveness of such policies across countries. The simplification into a dummy variable may thus underestimate the nuanced role of policy quality and implementation.

Third, the study does not explicitly account for other institutional, regulatory, or macroeconomic factors, such as political stability, rule of law, or energy prices, that could simultaneously affect both financial sector development and renewable energy investment. Although fixed effects models mitigate time-invariant omitted variable bias, unobserved time-variant influences remain a potential source of endogeneity.

While robust standard errors address heteroskedasticity, serial correlation, and cross-sectional dependence issues, the study does not implement instrumental variable techniques or dynamic panel models, which could strengthen causal inference in the presence of feedback effects.

Future research may address these limitations by incorporating more granular policy indicators, expanding the set of institutional variables, and employing advanced econometric strategies such as system GMM or panel VAR approaches.

CONCLUSION

The aim of this study is to explore the extent to which banking sector assets serve as a financial driver for renewable energy development, and how the implementation of FiTs can incentivize banks to allocate more resources toward renewable energy projects.

The study employed an unbalanced panel dataset comprising 66 countries from 2000 to 2020 to achieve this aim. A fixed effects panel regression model, extended with time dummies, was employed to control for unobserved heterogeneity across 66 countries and global temporal shocks. Diagnostic tests indicated the presence of serial correlation and cross-sectional dependence, which were addressed using cluster-robust standard errors. The analysis finds that banking sector development, in isolation, does not significantly influence the share of renewable energy consumption. However, the interaction between FiTs' policies and banking assets yields a significant and positive effect. This suggests that policy frameworks offering price stability and guaranteed revenue streams are essential in making renewable projects viable for banks. This points to the importance of institutional design in aligning financial sector incentives with climate goals.

The findings imply that banks, while not intrinsically oriented toward funding capital-intensive, long-term projects such as renewables, can be mobilized under appropriate policy conditions. In this context, FiTs serve as important enabling mechanisms that reduce risk and improve the predictability of returns, which are key considerations in banking investment decisions.

Rather than issuing rigid policy prescriptions, the results invite careful reflection on the importance of tailoring financial instruments to local banking structures. Countries with relatively mature financial systems may find FiTs particularly effective in unlocking capital from the financial sector, particularly banks. In contrast, others may require complementary de-risking instruments or blended finance approaches. Future research could explore how variations in banking regulation, credit risk assessment frameworks, or monetary policy settings shape the capacity of national banks to support the energy transition.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. List of countries

Albania	Ghana	Mongolia
Algeria	Greece	Morocco
Argentina	Hungary	Netherlands
Armenia	Iceland	New Zealand
Australia	India	North Macedonia
Austria	Indonesia	Norway
Belgium	Ireland	Poland
Bosnia and Herzegovina	Israel	Portugal
Brazil	Italy	Romania
Bulgaria	Japan	Russia
Canada	Jordan	Saudi Arabia
Chile	Kazakhstan	Slovak Republic
China	Kenya	Slovenia
Croatia	Korea	South Africa
Cyprus	Latvia	Spain
Czech Republic	Lithuania	Sweden
Denmark	Luxembourg	Switzerland
Dominican Republic	Malaysia	Turkey
Ecuador	Malta	Ukraine
Estonia	Mauritius	United Kingdom
France	Mexico	United States
Germany	Moldova	–

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