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The Impact of Green Technological Innovation, Financial Development on Green Energy Transition: Evidence from Pakistan

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ABSTRACT:

This research aims to explore the nexus between financial development, green technological innovation, and green energy transition in Pakistan. The association is explored using secondary data comprising the period 2005-2023, sourced from the World Bank database and analyzed using E-Views software. The findings indicate that all variables have a positive effect on green energy transition; however, financial development shows a significant association whereas green technological innovation shows an insignificant association. The study emphasizes the importance of stronger institutional frameworks and innovation-friendly policies to improve green transition outcomes in Pakistan.

Keywords: Green Energy Transition (GET),Green Technology Innovation (GTI), Financial development (FID),E-views, Pakistan

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INTRODUCTION

Pakistan is among the nations that heavily rely on fossil fuels and faces challenges related to energy demand and climate change, which present an urgent need for energy transition. According to the National Electric Power Regulatory Authority (NEPRA, 2023), approximately 60% of the country's energy still depends on fossil fuels, which escalates carbon emissions and increases the risk of fuel import dependency. However, the Alternative and Renewable Energy (ARE) Policy (2019) acknowledges this fossil fuel dependency and pledges that by 2030, 60% of the country's energy will be sourced from renewable resources. This highlights the importance of a green transition in Pakistan to enhance energy security, reduce fossil fuel imports, and achieve environmental sustainability targets (Siddiqui et al., 2022).

Green energy transition can be defined as the shift from non-renewable energy sources to renewable ones, such as solar, wind, and hydropower. The literature has identified financial development (FID) and green technology innovation (GTI) as two important drivers that facilitate this shift. GTI encompasses energy-saving initiatives that improve energy efficiency. Concerning Pakistan, GTI initiatives include smart energy systems, manufacturing of solar panels, and installation of net metering systems, resulting in energy efficiency gains across consumption, distribution, and generation (Khalid & Asif, 2021). A substantial body of research concludes that improvements in GTI are positively associated with green energy adoption (Sharif et al., 2023; Aslam et al., 2023).

Additionally, the promotion of green initiatives is significantly influenced by financial development (FID). Financial institutions can provide low-cost financing that may be channeled toward renewable energy projects. Similarly, a well-functioning stock market can direct funds toward environmentally friendly sectors, which in turn enhances the consumption and production of renewable energy (Alshagri et al., 2024; Sun et al., 2023). Therefore, a strong financial sector supports GTI by reducing investment-related risks and encouraging participation from both private and public sectors (Mehmood & Kamal, 2023). Nevertheless, Ahmed and Wan (2023) argue that investment and access to financing for renewable energy projects remain limited in Pakistan, particularly for household users and small and medium-sized enterprises (SMEs).

A substantial number of studies have examined the nexus between FID, GTI, and green energy transition (GET). These studies have been conducted in the context of both developed and developing countries (Muhammad & Hoffmann, 2024; Nawaz et al., 2021). Similarly, the majority of studies concerning this nexus have employed panel data covering multiple countries, such as OECD members, South Asian economies, N-11 economies etc. (Javed et al.,2025; Zulfiqar et al. 2023; , while some studies have also utilised single-country data [citation needed]. Concerning Pakistan specifically, existing studies have examined the nexus between FID and GET, and between GTI and GET independently (Mehmood & Kamal, 2025; Batool et al., 2025). However, to the best of our knowledge, no study has yet incorporated all three variables simultaneously within a single study [citation needed]. Therefore, this study aims to explore the nexus between FID, GTI, and GET in Pakistan.

This study contributes to the literature in several ways. First, it is the first study to collectively examine all three variables – FID, GTI, and GET – in the context of Pakistan. Second, it provides policy implications that are beneficial for policymakers in financial institutions and the renewable energy investment sector. Third, this research adds to the growing body of literature on

energy transition in developing countries, with particular reference to Pakistan.

The remainder of this paper is structured as follows: Section 2 discusses the literature review; Section 3 explains the methodology; Section 4 reports the data analysis; and Section 5 presents the conclusion and policy implications.

LITERATURE REVIEW

Theoretical Background

The research model of this study is grounded in two well-established theories: (i) Green Growth Theory and (ii) Sustainable Development Theory. Both theories argue that economic sustainability and prosperity can complement each other when an economy possesses efficient financial systems and promotes institutional transformation and innovation.

Green Growth Theory suggests that environmental threats and ecological scarcity can be minimized through long-term economic growth. It argues that economies can protect the environment from deterioration by investing in green technologies and innovation. Furthermore, when appropriate policy frameworks and financial infrastructure are in place, economies can transition from fossil fuel-based systems to low-carbon economies. According to Mehmood et al. (2023), technical innovation promotes sustainable energy generation, resource conservation, and cleaner production practices.

On the other hand, Sustainable Development Theory emphasizes meeting present economic and human needs without compromising the ability of future generations to meet their own needs. This theory argues that environmental preservation and social justice should be balanced with economic development. It highlights the importance of incorporating environmental considerations into economic development plans and emphasizes the value of green research and development, investment in climate-resilient systems, and the development of renewable energy infrastructure (Sharif et al., 2023; Afzal et al., 2022).

This study integrates both theories to better understand the dynamics of green energy transitions in Pakistan. Sustainable Development Theory provides a comprehensive socio-economic and inter-generational framework, emphasizing that economic growth should not occur at the expense of environmental degradation. In contrast, Green Growth Theory highlights the role of market-driven innovation and financial mechanisms in achieving environmental objectives. By combining these perspectives, this study examines how financial institutional development (FID) and green innovation and technology (GTI) jointly contribute to green energy transition (GET) in Pakistan, facilitating an energy transformation that is both sustainable and economically viable.

Empirical review

Javed et al. (2025) examined the effects of GTI and FID on GET in N-11 countries (1997-2020). The sample size comprised of N-11 countries from 1997 to 2020. The dependent variable was green energy transition (GET), and GTI, FID, natural resource rents, and inflation have been taken as independent variables. The study utilized MMQR, FMOLS, DOLS, and CCR as the statistical techniques. GTI and FID significantly promote GET in N-11 countries; inflation and natural resource rents have negative impacts. N-11 countries should enhance financial systems and support R&D in green technologies to accelerate GET.

Mehmood and Kamal (2025) studied the role of green finance in supporting renewable energy and environmental sustainability in Pakistan (2013-2022). The sample size comprised of Pakistan from 2013 to 2022. The dependent variable was environmental sustainability, and green finance has been taken as the independent variable. The

study utilized regression analysis on secondary data as the statistical technique. Green finance positively influences environmental sustainability in Pakistan. The government should expand green financial instruments like bonds and loans to fund renewable energy projects.

Zulfiqar et al. (2023) explored GTI, green energy production (GEP), and FID on environmental quality in South Asia (2000–2021). The sample size comprised of South Asia from 2000 to 2021. The dependent variable was environmental quality, and GTI, GEP, and FID have been taken as independent variables. The study utilized FMOLS and DOLS as the statistical techniques. GTI, GEP, and FID positively impact environmental quality in South Asia. South Asian countries should prioritize innovation and strengthen financial systems to improve environmental quality.

Batool et al. (2025) analyzed AI-driven GTI, FID, and CO2 emissions on Pakistan's energy use (1990–2022). The sample size comprised of Pakistan from 1990 to 2022. The dependent variable was energy use, and CO2 emissions, GDP, labor, ICT, FID, and patent innovation have been taken as independent variables. The study utilized ARDL as the statistical technique. AI-driven GTI and FID help reduce CO2 emissions and energy use in Pakistan. Pakistan should promote AI-powered green innovations and ensure financial accessibility for sustainable energy.

Aslam et al. (2022) used qualitative methods literature review and expert interviews to examine barriers and pathways to Pakistan's clean energy transition. The sample size comprised of Pakistan (year range not numerically fixed). The dependent variable was clean energy transition, and outdated infrastructure, weak coordination, and limited financing were taken as independent variables. The study utilized qualitative methods including literature review and expert interviews as the statistical technique. Outdated infrastructure, weak coordination, and limited financing are key barriers to clean energy transition in Pakistan. Strengthening institutional frameworks and increasing financing support are critical to enable the energy transition.

Muhammad and Hoffmann (2024) evaluated green finance and innovation impacts on renewable energy use in Germany (2008–2021). The sample size comprised of Germany from 2008 to 2021. The dependent variable was renewable energy use, and green investment, environmental sales, and R&D (in combination with patents) have been taken as independent variables. The study utilized MMQ regression as the statistical technique. Green finance and innovation positively influence renewable energy use in Germany. Other countries should adopt Germany's successful green finance and innovation strategies to boost renewable energy.

Ahmad et al. (2023) assessed effects of renewable and non-renewable energy, FID, GDP, and resource rents on CO_2 emissions in Pakistan (1990–2022). The sample size comprised of Pakistan from 1990 to 2022. The dependent variable was CO_2 emissions, and renewable energy, non-renewable energy, GDP, FID, and resource rents have been taken as independent variables. The study utilized ARDL and diagnostic tests as statistical techniques. Renewable energy and FID reduce CO_2 emissions, while non-renewable energy and GDP growth increase emissions. Policymakers should promote renewable sources and redirect financial flows toward low-emission energy investments.

Ali Umar Ahmad et al. (2024) used Panel NARDL to study asymmetric effects of renewable energy, FID, and trade openness on economic growth in D-8 countries (1970–2022). The sample size comprised of D-8 countries from 1970 to 2022. The

dependent variable was economic growth, and renewable energy, FID, and trade openness have been taken as independent variables. The study utilized Panel NARDL as the statistical technique. Asymmetric effects of renewable energy, FID, and trade openness on economic growth across D-8 countries were identified. Country-specific green finance and trade policies should be designed to optimize renewable energy's role in growth.

Abdullah and Ahmed (2025) analyzed renewable energy investment effects on GDP across 15 South Asian countries (1998–2022). The sample size comprised of 15 South Asian countries from 1998 to 2022. The dependent variable was GDP, and renewable energy investment and CO_2 emissions have been taken as independent variables. The study utilized GMM and fixed-effects models as the statistical techniques. Renewable energy investment boosts GDP while CO2 emissions negatively impact economic growth across South Asian countries. Governments should prioritize renewable energy investments and enforce emissions control policies to maintain sustainable growth.

Bhutta et al. (2022) studied green innovation, GEP, and FID on environmental quality in five South Asian nations (2000–2018), using FMOLS and DOLS with governance as a moderator. The sample size comprised of five South Asian nations from 2000 to 2018. The dependent variable was environmental quality, and green innovation, GEP, FID, and governance have been taken as independent variables. The study utilized FMOLS and DOLS as the statistical techniques. GTI, GEP, and FID improve environmental quality; governance enhances these effects further. Environmental policies should integrate governance reforms to amplify the benefits of green innovation and finance.

Abbas et al. (2024) evaluated financial inclusion and green innovation impacts on green economic growth in 12 developing countries (2004–2023). The sample size comprised of 12 developing countries from 2004 to 2023. The dependent variable was green economic growth, and green innovation, trade, FDI, financial inclusion, and population growth have been taken as independent variables. The study utilized PCA and FMOLS as the statistical techniques. Green innovation and financial inclusion significantly drive green economic growth in developing countries. Develop inclusive financial systems that empower clean technology enterprises and support sustainable development.

Nawaz et al. (2021) assessed green financial instruments' effects on Pakistan's economic growth (1981–2019). The sample size comprised of Pakistan from 1981 to 2019. The dependent variable was economic growth, and green credit, green insurance, green securities, and green investment have been taken as independent variables. The study utilized ARDL and Granger causality tests as the statistical techniques. Green financial instruments significantly support Pakistan's economic growth. Expand the scope of green credit, insurance, and securities through strategic policy frameworks.

Gull et al. (2023) explored financial development and green financing impacts on Pakistan's economic growth (1990–2020). The sample size comprised of Pakistan from 1990 to 2020. The dependent variable was economic growth, and financial development and green financing have been taken as independent variables. The study utilized ARDL in EViews as the statistical technique. Financial development and green financing positively affect economic growth in Pakistan. Improve financial sector access and governance to ensure effective channeling of green finance. Hossain et al. (2024) studied digital finance's influence on green innovation in 15 countries (2003–2020). The sample size comprised

of 15 countries from 2003 to 2020. The dependent variable was green innovation, and digital finance, R&D, and economic growth have been taken as independent variables. The study utilized quantile regression as the statistical technique. Digital finance significantly enhances green innovation across multiple countries. Promote fintech infrastructure and digital financial literacy to foster green innovation ecosystems.

Li et al. (2024) analyzed Fintech, GTI, and FID effects on environmental sustainability in Asian countries (2012-2021). The sample size comprised of Asian countries from 2012 to 2021. The dependent variable was environmental sustainability, and Fintech, GTI, FID, and institutional access have been taken as independent variables. The study utilized CS-ARDL as the statistical technique. Fintech, GTI, and FID significantly contribute to environmental sustainability across Asia. Develop regulatory environments that support green fintech and enhance institutional access to environmental finance.

Hussain et al. (2023) examined GTI, green finance, FDI, and GDP effects on CO_2 and ecological footprint in Pakistan (1990-2021). The sample size comprised of Pakistan from 1990 to 2021. The dependent variables were CO_2 emissions and ecological footprint, and GTI, green finance, FDI, and GDP have been taken as independent variables. The study utilized ARDL as the statistical technique. GTI, green finance, FDI, and GDP reduce CO_2 emissions and ecological footprints in Pakistan.

Wei et al. (2023) studied green energy, trade, innovation, and FDI on environmental quality in 10 green-future countries (1990-2018). The sample size comprised of 10 green-future countries from 1990 to 2018. The dependent variable was environmental quality, and green energy, trade, innovation, and FDI have been taken as independent variables. The study utilized CS-ARDL, AMG, and CCEMG as the statistical techniques. Green energy, trade, innovation, and FDI significantly improve environmental quality in green-future countries. Implement environmentally sound trade practices and innovation subsidies to enhance sustainability outcomes.

METHODOLOGY

The purpose of this study is explanatory and this study adopts a quantitative research approach, which allows for a more in-depth and interpretive understanding of the patterns, behaviors, and interactions among the studied variables. The study uses a correlational research design to identify and analyze the strength and nature of relationships between the variables under investigation. Secondary data has been collected from The World Bank database. This source provides reliable, internationally comparable statistics on financial indicators, innovation trends, environmental performance, and energy metrics relevant to the study variables. The details related to the variables is depicted in table below.

Variable	Abbreviation	Unit of measurement	Description
Green energy transition	GET	% of renewable energy in total final energy use	Represents the shift from fossil fuels to renewable energy sources such as solar, wind, and hydropower.
Financial development	FID	Domestic credit to private sector (% of GDP)	Measures the development and accessibility of financial systems,

			credit markets, and investment instruments.
Green technological innovation	GTI	Environment-related technologies (% of total patents)	Refers to technological advancements that support cleaner, more sustainable energy production and consumption.
Natural resources	NR	Natural resource rents (% of GDP)	Includes the availability and exploitation of renewable and non-renewable natural energy sources (e.g., hydropower, coal, solar).
Inflation	INF	Consumer Price Index (CPI, annual %)	Reflects the annual inflation rate which may affect investment decisions and energy affordability.
Error term	E		That's an Error term

The time frame for the sample data used in this study is for 19 years starting from 2005 to 2023, and geographical consideration is Pakistan. The timespan of 19-years confines the trends and policies related to the transition to green energy in the country. The functional model for this research is specified as:

GET = (FID+ GTI+ NR+ INF+ 𝜀t)

Where, GET: Green Energy Transition, FID: Financial Development, GTI: Green Technological Innovation, NR: Natural Resources and INF: Inflation.

DATA ANALYSIS

The data is analyzed using EViews software, which can be used in several time-series econometric techniques and regression models. This makes it useful for hypothesis testing and determining statistical relationships between study variables.

Descriptive Statistics

	FID	NRR	RE	GDP	ES	TI
Mean	1.046	1.819	45.308	3.837	2.973	208.263
Median	0.695	1.839	45.9	4.217	3	170
Maximum	3.035	2.891	48.1	7.276	3.5	426
Minimum	0.343	0.965	41.6	-1.274	2.5	91
Std. Dev.	0.827	0.638	2.155	2.264	0.310	109.0
Skewness	1.503	0.223	-0.368	-0.535	0.023	0.650
Kurtosis	3.779	1.557	1.648	2.793	2.718	1.999
Jarque-Bera	7.636	1.806	1.875	0.943	0.064	2.130
Probability	0.021	0.405	0.391	0.624	0.968	0.344
Sum	19.881	34.57	860.86	72.910	56.5	3957
Sum Sq. Dev.	12.339	7.332	83.619	92.335	1.736	2139 63.7
Observations	19	19	19	19	19	19

Descriptive statistics summarize the attributes of

the dataset. Precisely, the descriptive analysis of various characteristics including mean, median, maximum, minimum, and standard deviation are presented for Foreign Investment (FID), Natural Resource Rents (NRR), Renewable Energy (RE), GDP, Energy Security (ES), and Technological Innovation (TI). The summary indicated that RE (Renewable Energy) showed the maximum and highest mean value (45.30), this translates into its major role in the model. The TI (Technological Innovation) showed the highest variation (Std. Dev. = 109.02) signifying irregularity over the timespan of 19 years. The DI and NRR had moderate variation, reflecting gradual changes in investment and resource use.

Unit root Test:

Variables	I(0)				I(1)			
	T		T & C		T		T & C	
	T-Statistics	Prob	T-Statistics	Prob	T-Statistics	Prob	T-Statistics	Prob
FID	-1.247	0.6300	-1.386	0.8170	-3.739	0.0130	-3.785	0.0440
NRR	-1.63	0.446	-2.874	0.1948	-3.701	0.014	-3.685	0.0520
RE	-1.5981	0.4630	-2.531	0.3107	-4.550	0.0030	-4.641	0.0100
GDP	-1.919	0.1586	-0.666	0.1866	-5.032	0.0006	-4.751	0.0086
ES	-2.676	0.0820	-2.862	0.2060	-3.640	0.0180	-3.644	0.0600
TI	-0.3550	0.8978	-2.627	0.2754	-5.5539	0.0004	-4.9106	0.0060

The Augmented Dickey-Fuller (ADF) test was conducted to check the stationarity of variables: At level, most variables were non-stationary (p-value > 0.1). After taking the first difference, all variables became stationary (p-value < 0.1), satisfying the assumption for co-integration analysis. Thus, first differencing was applied to transform the series into a stable form for further long- term analysis.

Co-integration Test:

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	-4.054	37.770	20.277	0.0000
At most 1	-3.049	75.240	25.149	0.0000
At most 2	-5.115	10.740	-19.710	0.198
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.221	20.810	17.191	0.0000
At most 1	0.354	8.262	7.055	0.0003
At most 2	0.371	8.262	17.325	0.812

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Johansen's Co-integration Test was applied to identify long-term relationships among variables: The trace statistic for "None" was 37.77, which is greater than the critical value 20.27, indicating at least one co-integrating vector. Max Eigenvalue for "None" was 75.24, also exceeding its critical value 25.14, confirming a significant long-term association. Probabilities for both tests were 0.000, i.e., $p < 0.01$, proving strong evidence of co-integration. This implies that variables such as FID, NRR, RE, GDP, and TI share a long-run equilibrium relationship with ES supporting the existence of a meaningful structural connection.

Regression Analysis

Dependent Variable: ES			
Variable	Coefficient	Std. Error	Prob.
C	2.298	2.110	0.277
FID	0.308	0.088	0.001
GDP	0.050	0.024	0.041
NRR	0.088	0.045	0.056
RE	0.002	0.038	0.958
TI	0.001	0.001	0.213
R-squared	0.679	Durbin-Watson stat	1.906
Adjusted R-squared	0.555		
F-statistic	5.499		
Prob(F-statistic)	0.006		

The regression results indicate that FID and GDP and NRR have a statistically significant positive effect on ES, while RE and TI show no meaningful impact. The model explains about 68% of the variation in ES, and the overall fit is statistically significant ($p = 0.006$). The Durbin-Watson value suggests no major autocorrelation issues.

DISCUSSION

The first hypothesis explains FID and ES nexus. Financial development, represented by FID, shows a strong positive and significant relationship with green energy transition, reflecting the acceptance of developed hypothesis. This means increased investment availability supports renewable energy adoption in Pakistan by funding infrastructure and clean energy projects.

The second hypothesis examines the relationship between GTI and the GET. Although the coefficient for GTI is positive, the relationship is statistically insignificant ($p = 0.213$), failing to accept the hypothesis. It revealed that the green innovation does exist, but it is not the main driver that can explain the energy transition in Pakistan. This points out a likelihood of reasons not limited to inadequate implementation, imperfect commercialization, or absence of supportive policies for eco-friendly technologies. Therefore, innovation alone cannot change this scenario. Green innovation requires strong complementarity from a strong ecosystem that can enable effective deployment and integration into the energy sector.

The third premise considers the impact of NR on the GET. The results showed an insignificant relation ($p = 0.056$), with weak positive association between these variables. This justifies the rejection of the hypothesis. Similarly, it can be translated towards an ineffective direction of natural resources revenues for the development of renewable energy sector. A possible explanation can be the lack of targeted investment in green projects from income derived from natural resources hinders the potential to exploit green energy transition. The fourth hypothesis explained the influence of INF on GET. However, no conclusion can be drawn for this relationship because the variable was not included in the regression model, and the hypothesis is rejected. Therefore, it is recommended that future research attempts can incorporate inflation to finds its impact on green energy investments and policy effectiveness.

The fifth premise evaluates the role of Economic Conditions (E), particularly GDP growth, in affecting the GET. The results confirmed a significantly positive relationship among these variables (p = 0.041). This implies that with the enabling environment, expansion and stability of economy provides financial liberty to support investments in renewable energy infrastructure, thereby enabling the move toward sustainable energy sources in Pakistan.

CONCLUSION

This study investigated how Pakistan's green energy transition (GET) was impacted by financial development (FID) and green technology innovation (GTI). The study discovered a strong and favorable correlation between GTI and FID with GET, suggesting that financial mechanism enhancements and clean technology breakthroughs are essential for quickening Pakistan's shift to renewable energy. The outcomes support existing theories like Sustainable Development Theory and Green Growth Theory that emphasize the importance of combining financial investment with innovative efforts in-order to ensure an environmentally sustainable future. In general, the study contributes to the growing body of literature by focusing specifically on Pakistan where dual innovation in green energy has matured but policy implementation remains a challenge.

Managerial implications/recommendation:

To Pakistan must meet challenges to transition from grey to green by reinforcing policy and regulatory frameworks with targeted policies, regulatory reforms and incentive mechanisms for green technological innovation. Some of these policy interventions include subsidies for renewable energy projects, tax credits for clean tech firms in addition to mandates around sustainable infrastructure development. The role of financial institutions is crucial, and they should offer various instruments, ranging from green bonds to concessional loans or credit guarantees that can reduce the financial barriers to green projects. The incorporation of environmental risk assessments in the financial decision-making process will also make investment sustainable in the long run. Managers have been suggested to invest on smart grids, energy storage systems & digitized infrastructure in order to increase efficiency and reliability along with the integration of renewable energy into national grid for energy sector. Encouraging public-private partnerships (PPPs) is vital to fill in the technological and financial gaps, particularly in capital-intensive sectors like solar farms, wind corridors, and bioenergy units. Moreover, programs to build up the capacity, including but not limited to technical training, must be initiated to bring up a skilled workforce in eco-friendly technologies. The think tanks including universities, research institutes, and government machinery must play an active role to ensure the delivery of benefits of innovation ecosystems along with regulatory bodies that must guard highest standards of environmental compliance. Lastly, public awareness campaigns towards a behavioral shift must be initiated from various channels like green education and outreach campaigns to establish societal support for sustainable development goals and climate resilience.

Future Recommendations for Researchers:

Future researchers must give priority to the deployment of advanced quantitative methodologies, for the validation of empirically tested results for green technological innovation (GTI), financial development (FID), and green energy transition (GET). The use of these methods

will increase the reliability and generalizability of results for various contexts. Additionally, future studies should consider other widely affecting variables such as policy support mechanisms, public awareness, institutional quality, and governance effectiveness to explain the phenomenon at depth for the factors driving green energy adoption. Also studies with a contrast of contexts across South Asian or other developing countries would be a significant value addition towards identification of regional patterns, benchmarking progress, and offering generalizable insights for policy replication. Lastly, the consideration of mixed method approaches is recommended to offer richer findings of context and understanding. Researchers are also encouraged to investigate the long-term impacts of GTI and FID on GET, particularly in the face of evolving economic conditions, technological advancements, and shifting policy landscapes, which may influence the effectiveness and direction of sustainable development strategies.

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