



Recognized by: Higher Education Commission (HEC), Government of Pakistan

Fintech, ICT and Natural Resource Rent Contribution in Achieving Sustainable Green Growth Across the Globe

Ahmed Zeb Khan

Undergraduate Student, Quaid-i-Azam School of Management Sciences,
Quaid-i-Azam University, Islamabad
ahmed23zeb@gmail.com

Wasim Abbas Shaheen *

Assistant Professor, Quaid-i-Azam School of Management Sciences,
Quaid-i-Azam University, Islamabad
wasim@qau.edu.pk

Usman Ullah

M.Phil Research Scholar, Quaid-i-Azam School of Management Sciences,
Quaid-i-Azam University, Islamabad
usmanullahdirv@gmail.com

Waqas

M.Phil Research Scholar, Quaid-i-Azam School of Management Sciences,
Quaid-i-Azam University, Islamabad (45320)
waqas@qasms.qau.edu.pk

* Corresponding Author

ABSTRACT

Despite green innovation receiving more attention as an aspect of global sustainable development, there is little thorough research about factors that promote it, especially the contributions of financial technology (Fintech), information and communication technology (ICT), and natural resources. To close this void, the study focuses on the global green innovation dynamics by looking at how natural resources consumption, growing fintech and ICT, and rising carbon emissions enter into an eco-friendly technological advancement equation. Following systematic steps, the research investigates how literacy rates shape the factors with green innovations and the role of economic growth, measured by per capita GDP, in mediating these relationships. They analyze panel data from WDI for the years 2004-2021 to demonstrate different facets of green innovation in the context of sustainability

achievements. The results showed that economic development and literacy levels strongly affect the ability of the green technology adopters and users. The study stresses, too, that there is an urgent need for coordinated policy frameworks and integrative strategies to fully utilize the potential of fintech and ICT for achieving environmental sustainability. These findings underscore the need to focus on specific approaches to improve green innovation within certain regions that may lag due to economic and educational gaps. This research lays out the approach provides the determinants and obstacles to green innovation of green innovation, seeks to design effective strategies for transitioning to greener economies, reducing climate change impacts, and preserving sustainable living conditions for future inhabitants.

Keywords: Green Innovation Dynamics; Fintech Sustainability Integration; ICT-Driven Environmental Solutions; Natural Resource Exploitation and Innovation; Economic Growth.

INTRODUCTION

The twenty-first century presents a range of unprecedented global challenges, with the escalating environmental crisis standing out as one of the most urgent. Rapid depletion of natural resources, rapidly increasing threat of climate change, and an ever-expanding ecological footprint are pushing the world to a critical point, demanding immediate and decisive action. It indicates the main causes of the total world emissions are brought on by various human activities and the exploitation of natural resources. Natural resource depletion can lead to significant environmental decline; however, if sustainable management practices are effectively implemented, it is possible to mitigate this impact and promote resource regeneration with the patterns of utilization (Lisha et al., 2023). Despite substantial scholarly concentration on environmental sustainability, there has been minimal progress in developing a comprehensive pathway that considers all contributing factors to achieve long-term sustainability (Liu et al., 2024). And the core solution of this response lies in the need for innovation. Green innovation, in turn, is also influenced by fintech. As stated by Liu et al. (2023), in the current era of encompassing green-infused economic and social transformation, the creation of a bridge between corporate green innovation and fintech takes vital practical significance. However, a significant amount of ground has still to be covered in terms of the context of regional economies. Also, as suggested by Sadiq et al. (2024), literature on environmental quality and green loans indicate that green financing significantly reduces CO₂ emissions, which have been increasing rapidly over the years, with a slight decline in the past few years in some nations. Yet, several researchers report the significant impact of green finance on climate quality, but a limited study has been done to analyze the impact and significance of fintech on green innovation.

In recent decades, the discussion on sustainability gained significant momentum, pushed by a communal recognition of the interrelationship between human activity and environmental damage. This paradigm transition highlights the necessity for businesses, governments, and communities to reconsider conventional methods of production and consumption. (Liu et al., 2023) emphasize exactly how in this

sustainable model, finance plays a revolutionary role in fostering company innovation. In an era that is becoming increasingly recognized for its commitment to sustainable development, the concepts of finance extend beyond conventional approaches to be an essential component in fostering innovation. Particularly, fintech has emerged as a dynamic facilitator that significantly fosters green innovation. The increasing integration of finance and technology creates diverse possibilities for green innovation development and its implementation, expanding the reach and influence of sustainable business practices. Fintech innovations are changing the financial services industry by encouraging more efficiency, transparency, and accessibility. These technological innovations play a critical role in sustainable projects and activities, which not only stimulate financial objectives that are consistent with environmental sustainability but also help to reduce the impact of climate change. Fintech thus occupies a unique position at the connection of environmental preservation and economic development, providing innovative solutions that ease the shift to a greener economy.

Sustainable development has become crucial with the rapidly increasing environmental challenges on a global scale and the threats of climate change, yet several barriers prevent green innovation from being effectively incorporated into the global economic and environmental framework, even in the face of remarkable technological innovations and rising environmental consciousness. Green innovation is in contradiction with unsustainable resource extraction, and unrealized Fintech and ICT potential impacts environmentally friendly progress. The natural balance of our planet is further threatened by rising CO₂ emissions. To better understand how natural resources, Fintech, ICT, and CO₂ emissions interact, this study will examine how these factors affect the development of green technology worldwide. The adoption and spread of green innovations are also influenced by differences in literacy and economic status. The core objective is to get an understanding of how these variables collectively work together to shape the global landscape of environmentally friendly technological developments. The remainder of the document is organized as follows: The second section, "Literature review," summarizes the literature review; the third chapter, "Methodology," goes over the model and data usage in brief; the fourth section, "Results," goes over the study's actual results; and the fifth and final chapter, "Conclusion and discussion," wraps up the investigation.

LITERATURE REVIEW

Green innovations are associated with eco-friendly technologies, whereas traditional resource exploitation methods often undermine environmental sustainability efforts. These developments facilitate the shift from conventional resource-intensive sectors to those that rely more on renewable energy sources that support the environment (Sun et al., 2020). One issue of academic inquiry is the relationship between innovation in green technology and natural resource dependence. While some scholars claim that greater reliance on natural resources inhibits innovation in green technologies, others maintain that such dependence encourages it (Ran et al., 2023; Qian et al., 2021; Zhang & Brouwer, 2020; Mehlum et

al., 2006). Evidence suggests that countries which overly rely on resource extraction have lower capacity to diversify their economies, and are more susceptible to stagnation, conflicts, and even corruption (Dai & Du, 2023). Moreover, Dai and Du (2023), Sun et al. (2020), and Zhao et al. (2023) argue that the G20 countries need to integrate green innovations into their policies to promote economic growth while reducing their dependence on natural resources. In addition, creation and management of policies is required to mitigate the resource curse, achieve sustainability in the G20, support fiscal decentralization, and promote green innovation. Such policies ensure optimal resource management, ensuring social, economic, and environmental sustainability, and just or equitable socio-economic resource distribution (Pan et al., 2022). Ullah and Shaheen (2024) analyze the connection between sustainable finance and technological innovation through the governance index and other economic measures. Their work focuses on the role of these components in sustainable development, especially for decreasing greenhouse gas emissions.

Moreover, the research of Feng & Li (2024) investigates the multifaceted nature of the relationships among natural resource rent (NRR) and other components such as fiscal decentralization (FD), green innovations, and market regulations of G20 countries which indicates that some balance exists among the natural resource rent, fiscal decentralization (FD), and market regulations is necessary for sustainable growth and escaping the resource curse. The findings advocate for stronger governance and innovation pioneers on the other hand as enabling tools for extracting the potential of natural resources and fiscal decentralization towards diversified, resilient economies underscoring the robust role of green innovations on sustainable development. Huang et al (2022) further analyzed the linkage of natural resource rent with environmental degradation in the United States. From 1970 to 2016, natural resource rents increased economic growth in China, alongside Ahmad et al (2022) studying dynamic relations of NRRs and environmental sustainability employing the ARDL approach. Lisha et al (2023) used the quantile regression of the moment to study the relation between sustainability, NRR, and green innovations for the years 2000 to 2019. Their findings show the NRR undermines sustainable development in all quantile strata.

Fintech has inherent sustainable traits that could stimulate green innovation in a material economy through channels like information sharing and the promotion of digital literacy (Liu et al., 2023). FinTech advancements are not just reviving sustainability's social and economic goals but also protecting the environment and slowing down climate change (Deng et al., 2019). Fintech acts as a catalyst to improve the digital literacy of human resources involved in green innovation initiatives (Fang Lei and Liu, 2021). As proposed by Li et al. (2023), FinTech's customized services and helps in green finance broadens the long-tail market and expands capital generation for eco-friendly initiatives through economies of scale. It also provides additional opportunities for diminishing the financial constraints of foster corporate green innovations. Furthermore, Tariq et al. (2024) investigate the finTech, which is based on digital technology, can successfully handle the mismatch of green financial

resources and quickly assess and find green innovation projects, as well as speed up and accurately financial institution money transfers. Increased fintech development is correlated with increased advancements in the financial market environment as well as higher innovation performance. Bilal and Shaheen (2024) highlight that innovative financial solutions like crowdsourcing and online financial offers are examples of ways to lessen a company's financial limits, which encourages creative endeavors. In a modern milieu that is marked by a heightened resonance with respect to sustainable development, the idea that finance can facilitate business innovation raises a hypothesis that includes green innovation as a component of a wider range of innovative endeavors that may be fueled by Fintech developments (Liu et al., 2023).

According to empirical research, fintech companies might lessen the financial barriers that businesses encounter in this situation by reducing the information asymmetry that frequently characterizes the interaction between banks and businesses (Liu et al., 2023). FinTech promotion makes the external financial environment for corporations better, encourages businesses to embrace green innovation, and greatly increases the efficacy of pre-lending review and post-lending risk management capability of green credit (Li, Du, et al., 2023). Prior to financing, FinTech can multichannel and thoroughly gather, examine, and analyze data (Zhu, 2019), reduce adverse selection (Balyuk, 2016), and moral hazard problems (Sutherland, 2018) caused by the asymmetry of market information, and precisely guarantee that businesses secure and efficiently apply money for green innovation projects. Second, FinTech's customized services and facilitation can greatly expand the long-tail market's potential, broaden the spectrum of individuals involved in green finance, enable more capital to be raised for environmentally friendly projects due to economies of scale, and provide more avenues for reducing financial barriers to corporate green innovation initiatives. Furthermore, FinTech, which is based on digital technology, can successfully handle the mismatch of green financial resources and quickly assess and find green innovation projects, as well as speed up and accurately financial institution money transfers (Li, Du, et al., 2023) creating a catalytic stimulus that encourages increased participation in these kinds of revolutionary endeavors (Liu et al., 2023). Abbas et al. (2024) highlight that enhancing consumer engagement within brand communities is a key marketing objective for strengthening the brand-consumer relationship. Similarly, Kumar et al. (2024) investigate the relative influence of different genders of social media fitness influencers (SMFIs) on consumers' decisions regarding supplement purchases.

Moreover, Mansoor et al. (2018) study the effects of different subtype advertising messages using geographic segmentation on consumer attitudes. Scholarly literature extensively discusses the effects of information technology on innovative activities with environmental concern. From national and local perspectives, various studies have analyzed the impact of information technology on green innovations (Du et al., 2023). Some of the more recent studies have pointed out sustainability through various measures, including information and communication technologies (Liu et al., 2022). Several scholars have pointed out that green ICT is more complex than conventional ICT and that its division of labor is much riskier and more challenging

due to the greater need for international technological collaboration (Barbieri et al., 2020; Li et al., 2022). Almalki et al. (2023) remarked that the development of green Internet of Things (IoT) technologies in smart cities facilitates environmentally sound development and enhancement of the environment.

Lee et al. (2023) examined the effect of green ICT on the ecological footprint empirically and found that the existence of non-market environmental protection legislation and more advanced global green ICT technologies mitigated environmental degradation. Furthermore, Chen et al. (2020) examined the innovation of the power-generating industry by measuring the relationship between innovation, regional industrial CO₂ emissions, and Euro low-carbon policy measures using data envelopment analysis (DEA). According to their research, the decrease of CO₂ emissions is inhibited by the progress of innovation. In addition, Shen et al. (2021) found that green innovation has both an indirect promoting effect and a direct inhibitory effect on CO₂ emissions. The indirect effect, however, is more noticeable. Globally, the advancement of technology and modern innovations is raising serious concerns about climate change. The majority of developed nations in the modern world have implemented smart transportation systems, smart cities, modernized industrial processes, and energy-saving technology; it is hoped that these advancements will reduce CO₂ emissions (Lennerfors et al., 2015).

The G20 nations are at the forefront of adopting advanced technologies and modern innovations to address climate change. Their leadership in implementing smart solutions and sustainable practices sets a crucial example for global efforts to combat CO₂ emissions and promote environmental sustainability (Emissions Gap Report, 2023). The influence of green innovation on the relationship between natural resources and sustainable economic growth has been explored by various scholarly works (Shah et al., 2022). Osabohien et al. (2023) studied the relationship of natural resources and other economic parameters, like growth in economic production, with the energy mix of China from 1971 to 2019. They demonstrated using autoregressive distributed lag (ARDL) and error correction modeling (ECM) that the clean energy transition programs of China are positively associated with the level of economic development and consumption of natural resources. Some Zhang et al. (2022) argued that there is a need to rethink the conventional approach towards economic development using a focus on green innovation. Also, Mircetic et al. (2022) provides insight that green innovation is pivotal for simultaneously achieving environmental protection and economic growth because it has the potential to cut costs and lessen damages to the environment at the tail end of the operations.

While studying the ecosystem of green innovation in G20 countries, the intersection of natural resources, financial and information and communication technologies, CO₂ emissions, development indices, and the literacy rate yields a remarkable gap in research. Even though literature does acknowledge these considerations, they are usually incorporated in a single framework devoid of an in-depth examination of the economic, technological, and social dynamics of various countries. There is a shortage of empirical studies on how nations can leverage natural resources for green innovation without falling into the resource curse, the direct

impact of FinTech ecosystems on eco-friendly projects, and the role of ICT in fostering green innovation. While the adverse effects of CO2 emissions are well-documented, the effectiveness of green innovations in mitigating these emissions is still underexplored. Additionally, the mechanisms through which economic development, literacy, and education promote green technologies require further investigation. There is an essential need for integrated research that not only studies these aspects separately but also explores their combined impact on fostering or inhibiting green innovation, to achieve a comprehensive understanding of sustainable development and environmental sustainability.

METHODOLOGY AND DATA

Variable Description

In our investigation of green innovation, we diverge from the traditional methodologies and instead adopt the approach which is used by (Brohi Awais Ahmed & Suzuki, 2023), focusing on the number of patent counts. This metric, derived from the World Development Indicators (WDI), considers global patent applications filed either through the Patent Cooperation Treaty or directly with national patent offices to secure exclusive rights for inventions. These inventions, encompassing new products or processes, represent innovative technical solutions, reflecting the core of green innovation. In our study, we examine the variable "Natural Resources" by measuring total natural resource rents, using data from the World Bank, in line with the methodology of Liu et al., 2024 and Lisha et al., 2023. To gauge the accessibility and adoption of financial technology within societies, we utilize the extent of Automated Teller Machine (ATM) networks as a proxy, following Afjal et al., 2023. This indicator reflects not only the physical infrastructure for financial transactions but also a society's technological sophistication and its readiness to integrate financial technologies. We further evaluate the use of the internet as a proxy measure for the integration of Information and Communication Technology (ICT) within a society, as done by Afjal et al. in 2023. This indicator reflects the extent to which digital technologies are integrated into daily activities including information dissemination, education, collaboration, and innovation. Lastly, we take into consideration the CO2 emissions as analyzed by Lisha et al. in 2023 and Wei et al. in 2023 which reflect the environmental impact of human activities and is expressed in metric tons per capita.

Table 1 Variable Description

Variables	Notion	Proxy	Data Source
Dependent Variable			
Green Innovation	GI	Total Number of patent applications	WDI
Independent Variables			
Natural resources	NRR	Natural resource Rent	WDI
Financial Technology	FIN	Automated teller Machine Network	WDI

ICT	ICT	Internet Usage	WDI
Co2	CO2	Metric Tons per capita emission	WDI
Mediating Variable			
Economic Development	PGDP	Per capita GDP	WDI
Moderating Variable			
Education Level	EDU	School enrollment, Primary (%gross)	WDI
Control Variable			
Industrialization	IND	Industry value added % of GDP	WDI
Trade	TRADE	Trade (% of GDP)	WDI
Technology adaptation	TECHA D	Mobile cellular subscriptions Per 100 People	WDI

This metric acts as a pivotal gauge of the ecological stressors attributable to societal consumption and production patterns.

Other Variables

Economic Development Level was included in Table 1 as a mediating variable in Wang et al. (2023) and functions as a per capita GDP proxy. In our case, it acts as a mediator in our analysis of the green innovation's determinants. This measure of economic development is vital because it provides insight on how the affluence and economic well being of a society is likely to influence its ability to develop and adopt green technologies. Secondary education is listed here as a moderating variable explaining that higher education attainment can improve the natural resource, financial technology, ICT, and CO2 emission response effectiveness towards green innovation and therefore enhance green innovation productivity. Education brings value by enabling the comprehension of issues involving technology and the environment and thus increases the level of impact that other variables have on green innovation.

Control Variables

In order to maintain the accuracy and reliability of our analysis on the determinants of green innovation, which we quantified by measuring the number of patent applications, we included as part of our control set industrialization, trade, and technology adoption associated with the innovation in question. Such factors represent more comprehensive socio economic, technologic, as well as ecologic considerations which may influence green innovation without direct relation to the primary independent factors posited in the study.

Data

For this research, we adopt a dataset from the World Development Indicators (WDI) which covers the years 2004 to 2021. WDI has an enormous database of development statistics which is reliable for several key aspects in our study cooling the number of patent applications, natural resource rents, ATM network density, internet usage, CO2 emissions, GDP per capita, and education. The dataset permits a comprehensive study of the correlation between technological advances, resource

consumption, environmental impact, and socioeconomic factors in terms of green innovation. Statistical analysis is done using STATA, a comprehensive statistical package with advanced data analysis features.

ANALYSIS AND RESULTS

Descriptive Statistics

Table 2 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LnGI	774	6.515	1.751	.693	10.284
lnNRR	774	1.491	1.179	.001	5.349
LnFIN	774	4.036	.807	.239	5.431
LnICT	774	3.948	.685	.956	4.595
lnCO2	774	1.671	.608	-.152	3.243
lnPGDP	774	9.575	1.073	6.924	11.803
lnEDU	774	4.629	.055	4.409	4.818

In table 2, the descriptive results shows that the dependent variable, green innovation has a mean of 6.515 and a standard deviation of 1.751, with a minimum value of 0.693 and a maximum of 10.284. This indicates a moderate level of variability in green innovation among the observations. Meanwhile, the variable Natural Resource Rent shows a mean of 1.491 with a higher standard deviation of 1.179, ranging from a minimum of 0.001 to a maximum of 5.349, suggesting significant diversity in natural resource rents. Financial Technology has a mean of 4.036 with a standard deviation of 0.807, with values ranging from 0.239 to 5.431, which suggests considerable variation. The Information and Communication Technology (ICT) variable has a mean of 3.948 and a standard deviation of 0.685, ranging from 0.956 to 4.595, reflecting a relatively lower variation compared to other variables. The variable CO2 Emissions has a mean of 1.671 and a standard deviation of 0.608, with values from -0.152 to 3.243 which indicates a moderate variation in CO2 emissions. The mediator, economic development level, measured by per Capita GDP shows a mean of 9.575 and a standard deviation of 1.073, with a minimum value of 6.924 and a maximum of 11.803, indicating considerable variation in economic development across the observations. Finally, the moderator, Education has a mean of 4.629 and a very low standard deviation of 0.055, with values ranging from 4.409 to 4.818, suggesting minimal variation in educational levels. Overall, the dataset reveals a diverse range of values across the variables, highlighting significant variations in green investment, natural resource rent, financial development, ICT, CO2 emissions, and per capita GDP, while educational levels appear to be more uniform.

Correlation

Table 3 VIF and correlation Matrix

Variables	VIF	lnGI	lnFIN	lnNRR	lnICT	lnCO2	lnPGDP	lnEDU
lnNRR	1.134	0.091	1.000					

LnFIN	1.906	0.298	-0.088	1.000				
LnICT	2.635	0.196	-0.104	0.631	1.000			
lnCO2	2.016	0.412	0.093	0.519	0.478	1.000		
lnPGDP	3.166	0.329	0.136	0.579	0.701	0.648	1.000	
lnEDU	1.25	-	-0.012	-	-0.267	-0.297	-0.080	1.000
		0.173		0.229				

The correlation between LnGI and LnEDU is -0.173. This negative correlation suggests that higher levels of education are somewhat associated with lower levels of green innovation in this dataset, which may reflect the complex dynamics between educational attainment and innovation efforts in green technologies. Natural Resource Rent (NRR) has a very weak negative correlation (-0.012), indicating almost no relationship between education levels and natural resource rents. Meanwhile, a moderate negative correlation (-0.229) exists between LnFIN and LnEDU, suggesting that higher levels of education are associated with lower levels of financial technology. Also, a moderate negative correlation (-0.267) exists between LnICT and LnEDU, indicating that higher education levels correspond with lower levels of ICT. Simultaneously, lnCO2 has a moderate negative correlation (-0.297), which suggests that higher education levels are associated with lower CO2 emissions. Lastly, the mediator, lnPGDP, has a weak negative correlation (-0.080), suggesting a slight inverse relationship between education levels and per capita GDP. Overall, the inclusion of lnEDU as a moderator provides a detailed understanding of the relationships among green innovation and its determinants.

The inverse relationships between LnEDU and a number of critical variables indicates that higher schooling may affect green innovation, financial technology, ICT and CO2 emissions in more nuanced manners. Furthermore, the VIF analysis was performed to measure the possible multicollinearity among the predictors in the model to guarantee that all of the independent variables included do not possess high degrees of intercorrelation that could bias the regression estimates. Based on the results, all of the VIF values are significantly under the generally accepted level of 10 which suggests that the special form of correlation under consideration does not pose a serious problem for the analysis performed. In particular, the highest VIF value is attributed to lnPGDP (per capita GDP) which stands at 3.166, indicating some degree of correlation with other variables. However, these figures do not raise concern and are still considered acceptable in econometric terms. lnICT (information and communication technology) ranks next with a VIF of 2.635 and lnCO2 (carbon dioxide emissions) rounds out the list with a VIF of 2.016, signifying low, albeit manageable, multicollinearity. Even so, the variable financial technology (LnFIN) bolsters such claims by reporting a VIF of 1.906.

The moderator (lnEDU) reports a relatively low correlation VIF value of 1.25 which indicates weak association with other predictors. Finally, the natural resource rent variable (lnNRR) showed also the least VIF among all of 1.134 indicating low collinearity. The overall average VIF regarding all considered variables in the model

is 2.018 which is still considerably lower than the threshold limit justifying dependability of the regression analysis. With regards to multiple regression analysis, these VIF figures cumulatively demonstrate that the independent variables included in the model are sufficiently orthogonal to one another. Such a detailed assessment confirms the credibility of regression results alongside drawing pertinent conclusions from the analytical study.

Cross Sectional Dependence

Table 4 Cross Sectional Dependence

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
LnGI	74.66	0.000	43	0.92	0.92
LnNRR	68.101	0.000	43	0.84	0.84
LnFIN	69.499	0.000	43	0.86	0.86
LnICT	73.558	0.000	43	0.91	0.91
lnCO2	69.831	0.000	43	0.86	0.86
lnPGDP	79.8	0.000	43	0.98	0.98

The results of the cross-sectional dependence test for the study's variables are quite interesting. The natural logarithm of Green Innovation (lnGI) appears to be highly cross-sectionally dependent with a CD-test score of 74.66. This was also verified with a p-value of 0 alongside a mean ρ of 0.92 which indicates strong correlation across the panel group's correlation. lnNRR alongside lnFIN also shows CD-test values of 68.101 and 69.499 with p-values of 0 indicating significant dependence. Their mean ρ s of 0.84 and 0.86 respectively also demonstrate support for this. The Information and Communication Technology (ICT) variable demonstrates strong cross-sectional dependence with a CD-test score of 73.558, p-value of 0, and a mean ρ of 0.91. Likewise, for the natural logarithm of CO2 emissions (lnCO2) with CD-test value of 69.831, and p-value of 0, mean ρ renders 0.86. Last but not the least, in regards to the mediator (lnPGDP) shows the greatest extensiveness of cross-sectional dependence when compared to all other variables, achieving a CD-test score of 79.8, p-value of 0 and mean ρ of 0.98.

Heteroskedasticity (Breusch-Pagan Test)

Table 5 Heteroskedasticity (Breusch-Pagan Test) Serial correlation

Variable	Var	sd = sqrt(Var)
LnGI	3.066193	1.751055
E	1.988263	1.410058
U	0	0

The result indicates that the null hypothesis of zero variance in the random effect ($\text{Var}(u)=0$) cannot be rejected. This means that there is no significant random effect in the model. Consequently, the random effects model does not provide a better fit than the simple OLS model. The absence of significant random effects suggests that variations across years do not have a significant impact on greeninnovation,n indicating that the influence of the variables on green innovation is consistent over time. These findings have important implications for our model selection. Since the

random effects are not significant, the use of a fixed effects or pooled OLS model might be more appropriate for this analysis. This result simplifies our econometric modeling, allowing us to focus on the impact of the explanatory variables without needing to account for unobserved heterogeneity across years. Such understanding provides a simpler and more effective approach to identifying the factors that influence green innovation.

Unit Root Tests

To check the stationarity of our variables, we used the second generation unit root test since it is crucial for panel data analysis with cross-sectional dependence. This includes the Cross-Sectionally Augmented Dickey-Fuller (CADF) and Cross-sectionally Im, Pesaran, and Shin (CIPS) tests. These are suited for panel data and their results are useful even with cross-sectional dependence. Most tests have critical values which if significantly lower than their critical value allow the null hypothesis of a unit root (non-stationary) to be rejected. In this case, all of the variables show test statistics with ample distance from the critical value indicating that they are stationary at level I(0). These results indicate that there is no need to difference the variables to attain stationarity, thus allowing the inclusion in regression models without further modification.

Table 6: 2nd Generation Unit Root Test

	CIPS		CADF	
	1(0)	1(1)	1(0)	1(1)
LnGI	-5.717	/	-5.717	/
LnNRR	-5.915	/	-5.915	/
LnFIN	-5.824	/	-5.824	/
LnICT	-5.832	/	-5.832	/
lnCO2	-5.642	/	-5.642	/
lnPGDP	-5.948	/	-5.948	/
LnEDU	-5.946	/	-5.946	/

A regression analysis must be free of spurious relationships, which can only be ensured through stationarity. The stationarity of these variables enhances the reliability of our regression analysis, thus allowing us to make decisions that are accurate and credible concerning the factors influencing green innovation. By ensuring that the data is stationary at the mean level, we limit the chances of biased results and strengthen the dependability of our econometric models. This initial action fortifies the dependability of subsequent analyses and conclusions pertaining to our examination of green innovation along with its influential factors.

Cointegration Tests

The test used for identifying the co-integration test is Pedroni, and the results of the co-integration test is given in table 7.

Table 7 Pedroni Test for Cointegration

Statistic	Value	p-value
Modified Phillips-Perron t	-9.412	0.000
Phillips-Perron t	-17.8652	0.000

Augmented Dickey-Fuller t	-18.0143	0.000
---------------------------	----------	-------

All three test statistics yield p-values of zero, which is far lower than any common significance level. This strongly indicates the null hypothesis of cointegration is rejected. The test result implies that there exists an equilibrium relationship in the long run among the variables in the panel. It shows that in the long run, the variables indeed fluctuate together and, moreover, around a certain equilibrium value. This cointegration supports the reliability of our model, showing that the chosen variables are appropriate in examining the factors of green innovation and its long-run effects. Lastly, the results from the Pedroni test verify that the variables in question from this study are indeed cointegrated, thereby validating the econometric analysis conducted and the causal relations postulated between green innovation and its determinants. This supporting evidence is fundamental to drawing reasonable conclusions and formulating effective policy recommendations from the outcomes of this research.

Fixed Effect Regression

Table 8 Fixed Effect Regression

LnGI	Coef.	St.Err.	t-value	p-value	[95% Conf Interval]	Sig
LnNRR	.104	.049	2.11	.035	.007 .201	**
LnFIN	.242	.094	2.58	.01	.058 .425	**
LnICT	-.561	.162	-3.46	.001	-.879 -.243	***
lnCO2	1.075	.132	8.17	0	.817 1.334	***
lnPGDP	.488	.098	5.00	0	.296 .68	***
LnEDU	-5.647	1.071	-5.27	0	-7.75 -3.544	***
IND	.016	.008	1.99	.048	0 .031	**
TECHAD	.003	.003	1.25	.21	-.002 .009	
Trade	-.015	.001	-13.52	0	-.017 -.013	***
Constant	27.868	4.982	5.59	0	18.087 37.649	***

Mean dependent var	6.515	SD dependent var	1.751
R-squared	0.371	Number of obs	774
F-test	49.039	Prob > F	0.000
Akaike crit. (AIC)	2720.975	Bayesian crit. (BIC)	2767.491

The coefficient for lnNRR (natural resource rent) is 0.104, with a standard error of 0.049, indicating a positive and significant relationship (p-value = 0.035) with green innovation, suggesting an increase in natural resource rent will lead to a moderate but significant increase in green innovation activities. Financial technology (lnFIN) also shows a significant effect on green innovation, with a coefficient of 0.242 and a standard error of 0.094 (p-value = 0.01), suggesting the role of financial advancements in fostering environmentally friendly technological innovations. Conversely, lnICT (information and communication technology) demonstrates a negative coefficient of -0.561 with a standard error of 0.162, indicating a significant

negative relationship. This suggests that higher levels of ICT development might be associated with reduced green innovation, potentially due to the initial focus of ICT on efficiency improvements rather than sustainability. The CO₂ emissions (lnCO₂) variable has a strong positive impact on green innovation, with a coefficient of 1.075 and a standard error of 0.132, establishing that higher emissions cause more significant innovation efforts to minimize environmental impacts. The mediating variable, lnPGDP (per capita GDP), has a positive coefficient of 0.488, highlighting that economic growth facilitates green innovation. The moderating variable, lnEDU (education), shows a strong negative effect with a coefficient of -5.647 (standard error = 1.071, p-value < 0.001). Higher levels of knowledge may result in more careful analyses and limited adoption of green technologies. Among the control variables, industrialization (IND) has a small but significant positive effect on green innovation (coefficient = 0.016, p-value = 0.048), while the technological advancement (TECHAD) variable, though positive, is not statistically significant (coefficient = 0.003, p-value = 0.21). Trade openness (trade) shows a significant negative relationship with green innovation (coefficient = -0.015, p-value < 0.001), indicating that higher trade volumes might be associated with reduced green innovation, potentially due to competitive pressures prioritizing cost over sustainability. The model has an R-squared value of 0.371, suggesting that approximately 37.1% of the variance in green innovation is explained by the independent variables in the model. The F-test value of 49.039 and a p-value of less than 0.001 indicate that the overall model is statistically significant. The constant term of 27.868 (standard error = 4.982, p-value < 0.001) provides the level of green innovation when all other factors are zero. Overall, these findings highlight the complex nature of green innovation, which is driven by economic, technological, and educational aspects, as well as larger socioeconomic situations.

Random Effect Regression

Table 9 Random Effect Model

LnGI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
LnNRR	.106	.048	2.21	.027	.012	.201	**
LnFIN	.25	.092	2.72	.007	.07	.431	***
LnICT	-.505	.137	-3.69	0	-.773	-.237	***
lnCO ₂	1.027	.122	8.44	0	.788	1.265	***
lnPGDP	.471	.093	5.08	0	.289	.653	***
LnEDU	-5.615	1.052	-5.34	0	-7.677	-3.553	***
IND	.015	.008	1.97	.049	0	.03	**
TECHAD	.004	.002	1.82	.069	0	.009	*
Trade	-.015	.001	-13.66	0	-.017	-.013	***
Constant	27.629	4.899	5.64	0	18.028	37.231	***
Mean dependent var	6.515		SD dependent var		1.751		
Overall r-squared	0.368		Number of obs		774		
Chi-square	444.410		Prob > chi2		0.000		

R-squared within 0.371 R-squared between 0.061

The random effects regression model provides an understanding of the relationship between the dependent variable (lnGI) and the other variables (lnNRR, lnFIN, lnICT, lnCO2, lnPGDP, lnEDU, IND, TECHAD, and trade). This regression was conducted using the `xtreg` command in STATA with random effects specified, and the choice of the random effects regression model for this analysis is guided by several considerations that make it suitable for the data and the research questions being addressed. Also, the dataset consists of panel data, which includes multiple observations over time for the same countries, which makes this regression suitable for the data. The results of the test reveal that the coefficient for lnNRR is 0.106, suggesting a positive and significant relationship with lnGI at the 5% level, with a p-value of 0.027. This suggests that an increase in natural resource rents is associated with an increase in lnGI. While financial technology has a coefficient of 0.250, which is significant at the 1% level (p = 0.007). This suggests a statistically significant relationship between financial development and lnGI. Also, information and communication technology shows a negative relationship with lnGI, with a coefficient of -0.505, highly significant at the 1% level (p = 0.000). This implies that higher levels of ICT are associated with a decrease in lnGI. Further, the coefficient for lnCO2 is 1.027, which is highly significant (p = 0.000). This positive relationship suggests that increased CO2 emissions are strongly associated with higher lnGI. The mediator, lnPGDP, has a coefficient of 0.471, indicating a positive and highly significant impact on lnGI (p = 0.000). The overall R-squared value of 0.368 indicates that approximately 36.8% of the variance in lnGI is explained by the model. The within R-squared value of 0.371 and between R-squared value of 0.061 detailed understanding of the model's explanatory power within and between panels, respectively. The Chi-square statistic of 444.410 is highly significant (p = 0.000), indicating the overall model fit. Overall, the random effects regression results highlight the significant relationships between lnGI and the selected variables, with several variables showing strong impacts at different levels of statistical significance.

GMM without Mediation

Table 10 GMM without mediation

LnGI	Coef.	St.Err.	t-value	p-value	[95% Conf Interval]	Sig	
L	.08	.006	13.08	0	.068	.091	***
LnNRR	.109	.027	4.00	0	.056	.163	***
LnFIN	.38	.028	13.64	0	.325	.434	***
LnICT	-.293	.046	-6.43	0	-.382	-.204	***
lnCO2	1.089	.07	15.63	0	.953	1.226	***
Mean dependent var	6.554		SD dependent var		1.771		
Number of obs	738		Chi-square		.		

The Generalized Method of Moments (GMM) regression analysis was

conducted to explore the determinants of green innovation (LnGI) without considering the mediating role of per capita GDP (LnPGDP). The model includes natural resource rents (LnNRR), financial technology (LnFIN), information and communication technology (LnICT), and carbon dioxide emissions (LnCO2) as key independent variables. Additionally, the lagged dependent variable (L) is included to capture the dynamic aspect of green innovation over time. The analysis shows that the coefficient for the lagged dependent variable (L) is 0.08, calculated with a standard error of 0.006 and a t value of 13.08. The p-value is 0.000 which indicates a significance level of 1%. This supports that prior values of green innovation, in fact, have positive impact on its current values owing to an enduring and incremental impact of the activities of innovation. Also, the coefficient for LnNRR is 0.109 with the associated standard error of 0.027 and t value of 4.00. The p-value is 0.000 which indicates a significance level of 1%. This indicates that higher green innovation is linked with the increase of natural resource rents. The reason for this is possibly due to greater financial resources accrued from the exploitation of resources that is later reinvested back into sustainable practices. For LnFIN, the coefficient is 0.38 with standard error of 0.028 and t-value of 13.64. The p-value for this is 0.000, valid at 1% significance level. This positively significant coefficient directs attention to the effect capital has on green innovation, which, in this case, is considering the enormous possibilities proclaimed by financial technology. The overwhelming access to new financial tools combined with rapid changes in fintech appears to greatly enhance endeavors directed towards sustainable development. In no particular order, LnICT has the following values – coefficient of -0.293, a standard error of 0.046 and a t-value of 6.43. This study establish an association within 1 percent significance due to the p-value of 0.000. The negative relationship suggest a possibility where higher degree of ICT is presumed to relate with lower degree of green innovation. This astonishing result can be attributed to the starting environmental burden of any ICT infrastructure development.

The model is highly significant as Chi-square test confirms the overall fit of the model. Hence, these findings reveal that natural resource rents, financial technology, and CO2 emissions significantly promote green innovation, highlighting the importance of economic resources and technological advancements in sustainable development. Conversely, the negative impact of ICT necessitates further investigation to understand the underlying dynamics and address potential adverse effects.

GMM With Mediation

Table 11: GMM with mediation

LnGI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sign
L	.073	.01	7.07	0.000	.053	.094	***
LnNRR	.074	.032	2.34	.019	.012	.135	**
LnFIN	.347	.068	5.07	0.000	.213	.481	***

LnICT	-.492	.069	-7.15	0.000	-.627	-.357	***
lnCO2	1.036	.075	13.73	0.000	.888	1.184	***
lnPGDP	.175	.029	6.10	0.000	.119	.232	***

Mean dependent var	6.554	SD dependent var	1.771
Number of obs	738	Chi-square	.

The regression is performed after including the mediator (lnPGDGP) along with the independent variables which indicate a significant relationship between the dependent variable lnGI and the stated variable. The results suggests that a unit increase in lnNRR is associated with a 7.4% increase in lnGI, significant at the 5% level. The variable lnFIN shows a strong positive relationship with lnGI, with a unit increase in lnFIN leading to a 34.7% increase in lnGI, significant at the 1% level. Conversely, lnICT has a negative relationship with lnGI, with a unit increase in lnICT leading to a 49.2% decrease in lnGI, also significant at the 1% level. The variables lnCO2 and lnPGDP both have positive relationships with lnGI. A unit increase in lnCO2 is associated with a 103.6% increase in lnGI while a unit increase in lnPGDP is associated with a 17.5% increase in lnGI, both significant at the 1% level.

Moderation Analysis

The coefficient associated with the lagged dependent variable (L) is 0.069 which comes with a standard error of 0.004 giving a t-value of 17.08. The value of p in this case is 0.000 which is significant at the 1% level. It can be noted that this p value confirms a strong significant t test. This coefficient is also equal to one and therefore proves useful for outline bounds forecasting. The econometric estimation indicates that green innovation is enduring and increases over time which in turn indicates that green innovation leads to higher innovation in the future further increasing innovation and ultimately leading to success.

Table 12 Moderation Results (GMM)

LnGI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L	.069	.004	17.08	0	.061	.077	***
lnPGDP_lnEDU	.104	.001	72.48	0	.101	.107	***

Mean dependent var	6.554	SD dependent var	1.771
Number of obs	738	Chi-square	.

This study built on the GMM regression analysis to study the interaction effect of per capita GDP (lnPGDP) and education level (lnEDU) on green innovation (lnGI) for moderating purposes. This enables an analysis of how the association between lnPGDP and lnGI changes with the level of education. It also incorporates the variable

L, representing the dependent variable, to capture the dynamics of green innovation over time. The estimated value for L is 0.069; the standard error for this is 0.004, while the t-statistic stands at 17.08. The p value equals zero, therefore it's statistically significant at the 1% threshold.

The model possesses a high degree of statistical significance, as indicated by the Chi-square test. Hence, these results highlight the critical role of education in enhancing the positive relationship between economic development and green innovation and provides significant information for policymakers and stakeholders looking to support sustainable development through targeted investments in education and economic growth initiatives.

Robustness through Mean group estimator

Table 13 Mean Group estimator

lnGI	Coef.	Std.Err.	z	P>z	Interval] [95%Conf.	
lnNRR	0.068	0.024	2.770	0.006	0.020	0.115
lnFIN	0.374	0.091	4.120	0.000	0.196	0.552
lnICT	-1.313	0.297	-4.420	0.000	-1.896	-0.731
lnCO2	0.959	0.070	13.670	0.000	0.822	1.097
lnPGDP	0.346	0.039	8.880	0.000	0.269	0.422
_cons	5.519	0.885	6.240	0.000	3.785	7.254

This allows for the variation in the relationships between the independent and dependent variables across different groups, making it particularly suitable when the assumption of uniformity in slopes is not valid. The results of the MG estimator are presented in the table, showcasing the coefficients, standard errors, z-values, p-values, and confidence intervals for each independent variable in relation to the dependent variable, lnGI (green investment). The independent variables include lnNRR (natural resource rents), lnFIN (financial development), lnICT (information and communication technology), lnCO2 (carbon dioxide emissions), and lnPGDP (per capita GDP). For NRR, the coefficient value is 0.068, suggesting that it is positively and statistically significantly related to GI (p value 0.006). Thus, higher resource rent directly translates to an increase of green investment. Greater value of lnFIN with a coefficient of 0.374, shows an equally positive and statistically significant relation to green investment (p value 0.000). This suggests that advanced financial system leads to greater amount of green investment. On the contrary, lnICT shows a value of -1.313 which suggests a negative and statistically significant effect to green investment (p value 0.000). This indicates that high level of information and communication technology may lead to lower green investment. With value of 0.959 for lnCO2, the coefficient indicates strong positive and statistically significant impact of carbon dioxide emissions on green investment (p value 0.000). This request is interpreted that greater amount of carbon dioxide emissions leads to higher green investment. Coefficient value for pgdp per capita is 0.346 suggesting green investment will have positive and statistically significant impact (p value 0.000). Thus, larger value of per capita gdp, increases the amount of green investment. The constant term (cons) have

a coefficient value of 5.519 which is also significant with (p value 0.000). This indicates a certain baseline level of investment with a certain model of independent variables.

CONCLUSION

As noted, the focus of this study is a comprehensive evaluation of the primary determinants of green innovation, attempting to untangle the web between the natural resources available, Fintech, ICT, CO₂ emissions, economic growth, and even literacy levels. Their findings seek to help understand the intricate relationship between these elements and how they work together to drive green innovation across the globe. The study, in particular, traces the astonishingly beneficial impact of Fintech and ICT on green innovation, but also raises serious issues regarding the depletion of natural resources and increasing CO₂ emissions. Economic growth and literacy levels seem to be critical factors that determine a country's ability to adopt and utilize green technologies. The rest of the analysis, however, reveals the presence of multicollinearity among these variables, as shown with the VIF, which underscores how complex and interrelated these relationships are. Such complexity can be geared towards achieving more sustainable environmental outcomes through the development of legislation and strategic policies aimed at Pragmatic Environmentalism ICT and Fintech while utilizing their enormous potential to transform the environment. In addition, this study contributes to sustainable development by pinpointing the constraints and drivers of green innovations. It calls for prompt proactive measures to curb the adverse impacts of climate change while hastening a shift to a low carbon economy. These results are very valuable to governments, business executives, and scholars because they offer a plan for maintaining the balance and sustainability prudent for the future of our world. Finally, this analysis illustrates the different aspects of green innovation and its crucial role in helping an society achieve sustainability objectives. This encourages all rounded strategies for green innovation and environmental sustainability by addressing the many interactions that influence social systems. The research enhances our comprehension of such innovations so that decisions and actions for encouraging the sustainability of future generations can be carried out thoughtfully.

Recommendations

With respect to the advantages that fintech and ICT have on green innovation, it is clear that policies directed towards fostering the growth and acceptance of these technologies need to be initiated. Such policies might stimulate investment in these technologies or create a regulatory framework that promotes innovation. Furthermore, the negative impacts of natural resource damage and CO₂ emissions underline the importance of having strict policies on the environment. These policies should encourage reducing resource depletion and emissions, thereby enabling green innovation. Moreover, policies directed towards stimulating economic growth which, in turn, enables the innovation of green technologies are needed. This may be achieved through investment in supporting business activities, fostering economic stability, and growth. Poised with the impact of literate citizens on green innovation, policies should aim towards improving literacy and education levels. This

encompasses expanding educational institutions, establishing literacy enhancement initiatives, and guaranteeing educational opportunities for everyone. Lastly, the presence of multicollinearity in the model implies that there are intricate relationships between the variables. Subsequent work should aim to determine these relations in order to better address the problem of green innovation.

REFERENCES

- Abbas, M., Nawaz, Z., & Fatima, A. S. (2024). Corporate social responsibility and brand community engagement: dual mediating role of brand and community identifications in the Chinese decor industry. *Fudan Journal of the Humanities and Social Sciences*, 17(1), 51-72.
- Afjal, M., Kathiravan, C., Dana, L. P., & Nagarajan, C. D. (2023). The Dynamic Impact of Financial Technology and Energy Consumption on Environmental Sustainability. *Sustainability* (Switzerland), 15(12). <https://doi.org/10.3390/su15129327>
- Aghabalayev, F., & Ahmad, M. (2023). Does innovation in ocean energy generations-related technologies in G7 countries reduce carbon dioxide emissions? Role of international collaboration in green technology development and commercial and monetary policies. *Environmental Science and Pollution Research*, 30(6), 14545–14564. <https://doi.org/10.1007/s11356-022-23081-x>
- Ahmad, F., Draz, M. U., Chandio, A. A., Ahmad, M., Su, L., Shahzad, F., & Jia, M. (2022). Natural resources and environmental quality: Exploring the regional variations among Chinese provinces with a novel approach. *Resources Policy*, 77, 102745. <https://doi.org/https://doi.org/10.1016/j.resourpol.2022.102745>
- Almalki, Faris. A., Alsamhi, S. H., Sahal, R., Hassan, J., Hawbani, A., Rajput, N. S., Saif, A., Morgan, J., & Breslin, J. (2023). Green IoT for Eco-Friendly and Sustainable Smart Cities: Future Directions and Opportunities. *Mobile Networks and Applications*, 28(1), 178–202. <https://doi.org/10.1007/s11036-021-01790-w>
- Balyuk, T. (2016). Financial innovation and borrowers: Evidence from peer-to-peer lending. University of Toronto-Rotman School of Management Toronto, ON, Canada.
- Barbieri, N., Marzucchi, A., & Rizzo, U. (2020). Knowledge sources and impacts on subsequent inventions: Do green technologies differ from non-green ones? *Research Policy*, 49(2), 103901. <https://doi.org/https://doi.org/10.1016/j.respol.2019.103901>
- Bilal, M. J., Shaheen, W.A. (2024), “Towards sustainable development: Investigating the effect of green financial indicators on renewable energy via the mediating variable” *Renewable Energy*. Volume 221 (119819). <https://doi.org/10.1016/j.renene.2023.119819>
- Bilal, M., ul Haq, A., & Qureshi, S. A. (2020). Moderating Effect of Corruption in Relationship of Cash Holding and Corporate Governance with Firm’s Performance: Evidence from Pakistan. *Journal of Managerial Sciences*, 14(3).
- Brohi Awais Ahmed AND Suzuki, Y. (2023). Does green innovation moderate

- between FDI and environmental sustainability? Empirical evidence from South Asia. *PLOS ONE*, 18(11), 1–15. <https://doi.org/10.1371/journal.pone.0288532>
- Chen, M. A., Wu, Q., & Yang, B. (2019). How Valuable Is FinTech Innovation? *The Review of Financial Studies*, 32(5), 2062–2106. <https://doi.org/10.1093/rfs/hhy130>
- Chen, Y., Liu, S., Wu, H., Zhang, X., & Zhou, Q. (2020). How can Belt and Road countries contribute to global low-carbon development? *Journal of Cleaner Production*, 256, 120717. <https://doi.org/https://doi.org/10.1016/j.jclepro.2020.120717>
- Cuevas-Vargas, H., Aguirre, J., & Parga-Montoya, N. (2022). Impact of ICT adoption on absorptive capacity and open innovation for greater firm performance. The mediating role of ACAP. *Journal of Business Research*, 140, 11–24. <https://doi.org/https://doi.org/10.1016/j.jbusres.2021.11.058>
- Cui, X., Umair, M., Ibragimov, G., & Dilanchiev, A. (2023). Does Remittances Mitigate poverty? An Empirical Evidence from 15 Selected Asian Economies. *The Singapore Economic Review*, 68. <https://doi.org/10.1142/S0217590823440034>
- Dai, S., & Du, X. (2023). Discovering the role of trade diversification, natural resources, and environmental policy stringency on ecological sustainability in the BRICST region. *Resources Policy*, 85, 103868. <https://doi.org/https://doi.org/10.1016/j.resourpol.2023.103868>
- Deng, X., Huang, Z., & Cheng, X. (2019). FinTech and Sustainable Development: Evidence from China Based on P2P Data. *Sustainability*, 11(22). <https://doi.org/10.3390/su11226434>
- Du, L., Wei, M., & Wu, K. (2023). Information technology and firm's green innovation: evidence from China. *Environmental Science and Pollution Research*, 30(43), 97601–97615. <https://doi.org/10.1007/s11356-023-29320-z>
- Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again). (2023). United Nations Environment Programme. <https://doi.org/10.59117/20.500.11822/43922>
- Fang Lei and Liu, X. and S. X. and Y. J. and D. S. and H. P. and T. S. (2021). Bayesian Inference Federated Learning for Heart Rate Prediction. In M. J. and C. G. and Y. K. Ye Juan and O'Grady (Ed.), *Wireless Mobile Communication and Healthcare* (pp. 116–130). Springer International Publishing.
- Feng, Z., & Li, Y. (2024). Natural resource curse and fiscal decentralization: Exploring the mediating role of green innovations and market regulations in G-20 economies. *Resources Policy*, 89, 104556. <https://doi.org/https://doi.org/10.1016/j.resourpol.2023.104556>
- Goldfarb, A., & Tucker, C. (2019). Digital Economics. *Journal of Economic Literature*, 57(1), 3–43. <https://doi.org/10.1257/jel.20171452>
- Huang, W., Wang, Q., Li, H., Fan, H., Qian, Y., & Klemeš, J. J. (2022). Review of recent progress of emission trading policy in China. *Journal of Cleaner Production*, 349, 131480. <https://doi.org/https://doi.org/10.1016/j.jclepro.2022.131480>

- Kumar, N., Nawaz, Z., & Samerguy, P. (2024). The power of social media fitness influencers on supplements: how they affect buyer's purchase decision?. *International Journal of Pharmaceutical and Healthcare Marketing*, 18(1), 27-46.
- Lee, C.-C., Chen, M.-P., & Wu, W. (2023). The role of GICT and environmental regulation in affecting ecological footprint. *Environmental Science and Pollution Research*, 30(19), 54770–54799. <https://doi.org/10.1007/s11356-023-25595-4>
- Lennerfors, T., Fors, P., & van Rooijen, J. (2015). ICT and environmental sustainability in a changing society. *Information Technology & People*, 28, 758–774. <https://doi.org/10.1108/ITP-09-2014-0219>
- Li, B., Chang, J., Guo, J., Zhou, C., Ren, X., & Liu, J. (2023). Do green innovation, I.C.T., and economic complexity matter for sustainable development of B.R.I. economies: moderating role of higher education. *Environmental Science and Pollution Research*, 30(20), 57833–57849. <https://doi.org/10.1007/s11356-023-26405-7>
- Li, B., Du, J., Yao, T., & Wang, Q. (2023). FinTech and corporate green innovation: An external attention perspective. *Finance Research Letters*, 58. <https://doi.org/10.1016/j.frl.2023.104661>
- Li, Y., Zhu, Z., Guan, Y., & Kang, Y. (2022). Research on the structural features and influence mechanism of the green ICT transnational cooperation network. *Economic Analysis and Policy*, 75, 734–749. <https://doi.org/https://doi.org/10.1016/j.eap.2022.07.003>
- Lisha, L., Mousa, S., Arnone, G., Muda, I., Huerta-Soto, R., & Shiming, Z. (2023). Natural resources, green innovation, fintech, and sustainability: A fresh insight from BRICS. *Resources Policy*, 80. <https://doi.org/10.1016/j.resourpol.2022.103119>
- Liu, J., Zhang, Y., & Kuang, J. (2023). Fintech development and green innovation: Evidence from China. *Energy Policy*, 183. <https://doi.org/10.1016/j.enpol.2023.113827>
- Liu, K., Mahmoud, H. A., Liu, L., Halteh, K., Arnone, G., Shukurullaevich, N. K., & Alzoubi, H. M. (2024). Exploring the Nexus between Fintech, natural resources, urbanization, and environment sustainability in China: A QARDL study. *Resources Policy*, 89, 104557. <https://doi.org/10.1016/j.resourpol.2023.104557>
- Liu, L., Li, Z., Fu, X., Liu, X., Li, Z., & Zheng, W. (2022). Impact of Power on Uneven Development: Evaluating Built-Up Area Changes in Chengdu Based on NPP-VIIRS Images (2015–2019). *Land*, 11(4). <https://doi.org/10.3390/land11040489>
- Mansoor, R., Zhang, J., Hafeez, I., Nawaz, Z., & Naz, S. (2018). Consumer attitude towards different location based advertisements types and their impact on purchase intention. *Journal of Management Information and Decision Sciences*, 21(1), 1-19.
- Mehlum, H., Moene, K., & Torvik, R. (2006). Institutions and the Resource Curse. *The*

- Economic Journal, 116(508), 1–20. <https://doi.org/10.1111/j.1468-0297.2006.01045.x>
- Mirčetić, V., Ivanović, T., Knežević, S., Arsić, V. B., Obradović, T., Karabašević, D., Vukotić, S., Brzaković, T., Adamović, M., Milojević, S., Milašinović, M., Mitrović, A., & Špiler, M. (2022). The Innovative Human Resource Management Framework: Impact of Green Competencies on Organisational Performance. *Sustainability*, 14(5). <https://doi.org/10.3390/su14052713>
- Naseer, M., Haq, A. ul, & Farooq, M. (2018). Antecedent of Employees' Career Satisfaction: An Empirical Investigation of Pharmaceutical Sector of Pakistan. *International Journal of Academic Research in Business and Social Sciences*, 8(7), 281–299
- Osabohien, R., Karakara, A. A., Ashraf, J., & Al-Faryan, M. A. S. (2023). Green Environment-Social Protection Interaction and Food Security in Africa. *Environmental Management*, 71(4), 835–846. <https://doi.org/10.1007/s00267-022-01737-1>
- Pan, X., Song, M., Wang, Y., Shen, Z., Song, J., Xie, P., & Pan, X. (2022). Liability accounting of natural resource assets from the perspective of input Slack—An analysis based on the energy resource in 282 prefecture-level cities in China. *Resources Policy*, 78, 102867. <https://doi.org/https://doi.org/10.1016/j.resourpol.2022.102867>
- Qian, X., Wang, D., Wang, J., & Chen, S. (2021). Resource curse, environmental regulation and transformation of coal-mining cities in China. *Resources Policy*, 74, 101447. <https://doi.org/https://doi.org/10.1016/j.resourpol.2019.101447>
- Ran, Q., Yang, X., Yan, H., Xu, Y., & Cao, J. (2023). Natural resource consumption and industrial green transformation: Does the digital economy matter? *Resources Policy*, 81, 103396. <https://doi.org/https://doi.org/10.1016/j.resourpol.2023.103396>
- Sadiq, M., Paramaiah, C., Joseph, R., Dong, Z., Nawaz, M. A., & Shukurullaevich, N. K. (2024). Role of fintech, green finance, and natural resource rents in sustainable climate change in China. Mediating role of environmental regulations and government interventions in the pre-post COVID eras. *Resources Policy*, 88. <https://doi.org/10.1016/j.resourpol.2023.104494>
- Shah, M. I., Foglia, M., Shahzad, U., & Fareed, Z. (2022). Green innovation, resource price and carbon emissions during the COVID-19 times: New findings from wavelet local multiple correlation analysis. *Technological Forecasting and Social Change*, 184, 121957. <https://doi.org/https://doi.org/10.1016/j.techfore.2022.121957>
- Shah, S., Khan, M., Haq, A. U., & Hayat, M. (2023). COVID-19 Precautions of Pakistani Banks in the Lens of Qualitative Study Approach. *Global Journal of Humanities and Social Sciences Research*, 2(2), 16-30.
- Shen, F., Liu, B., Luo, F., Wu, C., Chen, H., & Wei, W. (2021). The effect of economic growth target constraints on green technology innovation. *Journal of Environmental Management*, 292, 112765. <https://doi.org/https://doi.org/10.1016/j.jenvman.2021.112765>

- Shahzadi, S., Khan, R., Toor, M., & Haq, A. U. (2018). Impact of external and internal factors on management accounting practices: a study of Pakistan. *Asian Journal of Accounting Research*, 3(2), 211-223.
- Spiezia, V. (2011). Are ICT Users More Innovative? *OECD Journal: Economic Studies*, 2011(1), 1–21. https://doi.org/10.1787/eco_studies-2011-5kg2d2hkn6vg
- Sun, Y., Ak, A., Serener, B., & Xiong, D. (2020). Natural resource abundance and financial development: A case study of emerging seven (E-7) economies. *Resources Policy*, 67, 101660. <https://doi.org/https://doi.org/10.1016/j.resourpol.2020.101660>
- Sutherland, A. (2018). Does credit reporting lead to a decline in relationship lending? Evidence from information sharing technology. *Journal of Accounting and Economics*, 66(1), 123–141. <https://doi.org/https://doi.org/10.1016/j.jacceco.2018.03.002>
- Tariq, M., Maryam, S. Z., Shaheen, W.A. (2024). Cognitive factors and actual usage of Fintech innovation: Exploring the UTAUT framework for digital banking. *Heliyon*, 10 (15) (ISSN: 2405-8440). <https://doi.org/10.1016/j.heliyon.2024.e35582> .
- Ullah, U., Shaheen, W.A. (2024) Empowering sustainable development through finance, economic factors, technology-innovation, and Governance Index for a flourishing future. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-024-05480-x>
- Wang, C., Qiao, G., Ahmad, M., & Ahmed, Z. (2023). The Role of the Government in Green Finance, Foreign Direct Investment, Technological Innovation, and Industrial Structure Upgrading: Evidence from China. *Sustainability (Switzerland)*, 15(19). <https://doi.org/10.3390/su151914069>
- Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., & Xiong, D. (2020). The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP 21 Agreements? *Journal of Environmental Management*, 271, 111027. <https://doi.org/https://doi.org/10.1016/j.jenvman.2020.111027>
- Wei, S., Jiandong, W., & Saleem, H. (2023). The impact of renewable energy transition, green growth, green trade and green innovation on environmental quality: Evidence from top 10 green future countries. *Frontiers in Environmental Science*, 10. <https://doi.org/10.3389/fenvs.2022.1076859>
- Yu, B., & Zhou, X. (2023). Urban administrative hierarchy and urban land use efficiency: Evidence from Chinese cities. *International Review of Economics & Finance*, 88, 178–195. <https://doi.org/https://doi.org/10.1016/j.iref.2023.06.033>
- Zhang, L., Huang, F., Lu, L., Ni, X., & Iqbal, S. (2022). Energy financing for energy retrofit in COVID-19: Recommendations for green bond financing. *Environmental Science and Pollution Research*, 29(16), 23105–23116. <https://doi.org/10.1007/s11356-021-17440-3>
- Zhang, Q., & Brouwer, R. (2020). Is China Affected by the Resource Curse? A Critical Review of the Chinese Literature. *Journal of Policy Modeling*, 42(1), 133–152.

<https://doi.org/https://doi.org/10.1016/j.jpolmod.2019.06.005>

Zhao, W.-X., Samour, A., Yi, K., & Al-Faryan, M. A. S. (2023). Do technological innovation, natural resources and stock market development promote environmental sustainability? Novel evidence based on the load capacity factor. *Resources Policy*, 82, 103397.

<https://doi.org/https://doi.org/10.1016/j.resourpol.2023.103397>

Zhu, C. (2019). Big Data as a Governance Mechanism. *The Review of Financial Studies*, 32(5), 2021–2061. <https://doi.org/10.1093/rfs/hhy081>.