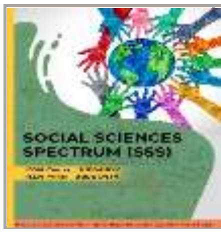

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Global Dynamics of Energy Use Sustainability, and R&D: Unlocking Green Innovation Through Environmental Regulations

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Abstract

The purpose of this study is to analyze the interdependencies among economic growth, energy consumption, foreign direct investment (FDI), environmental sustainability, and research & development (R&D) in green innovation behavior from 2000-2020 for 49 countries across the globe. The study tests these predictions using the Generalized Method of Moments (GMM) for robust analysis and investigates how financial development mediates these relationships, which is moderated by environmental regulation. They find that FDI, energy consumption, and R&D all have a significant role in driving green innovation. Financial development, in contrast to common intuition and hypothesis, meddles not a lot among monetary growth energy utilization, FDI, ecosystem sustainability, R&D, green innovation relationship. The remarkable impact of environmental regulations may partially cause a considerable reduction in the relationship between financial development and green innovation. These findings do indicate the importance of policy targeted at continuing to direct and effect green innovation. In summary, the direct effects of FDI and energy consumption as well as R&D are important for policymakers to consider in relation to financial development such that environmental regulations serve a moderating role in ensuring sufficient economic growth while maintaining an acceptable level of sustainable environment.

Keywords: Eco-financial Interference, Regulatory Dampening Effect, Green Innovation Synergies, Sustainability-Modulated Growth, Transnational Eco-Innovation Dynamics.

1. Introduction

Environmental deterioration has become a major peril to the survival of humanity, leading numerous groups and populations to embrace green innovations (GI) as a tactic for safeguarding the environment and promoting economic growth. It is essential to prioritize both environmental sustainability & economic profitability (Fliaster and Kolloch 2017). GI assists firms in attaining sustainability competitive advantages (Hur, Kim and Park 2013). Currently, in the world of business, Effective execution of GI not only enhances market positioning but also entices clients, provides environmentally friendly services, and establishes a competitive advantage. As a result, GI has gained significant importance among organizational administrators and scholars. Sustainability is defined as the ability to meet current needs without compromising the ability of generations to come to meet their own needs. To be more precise, not many academics studying innovation management are looking into the creation of new goods or services associated with green innovations. Foreign direct investment (FDI) inflows worldwide increased by 3.0% in 2019, reaching $1.5 trillion, according to the most recent statistics from UNCTAD (2020). China, the country that gets the most foreign direct investment (FDI), had a surge from $3.5 billion by 1990 up $126.3 billion in 2015, as reported by Liu et al. (2018). Despite the economic success brought about by increasing foreign direct investment (FDI), China continues to face significant environmental pollution problems.

The World Health Organization's 2016 Global Air Pollution Database lists 30 Chinese towns among the world's 100 most polluted in 2016. In addition, water contamination is a big issue because the amount of sewage from homes grew from 228 billion metric tons in 2001 to 535 billion tons in 2017. Contamination of the environment is becoming an ever-greater danger to public health and societal progress. We must act swiftly in response to the worsening environmental situation and the increasing FDI. Governments must invest in R&D initiatives if they want to create and deploy renewable energy technology and make sure it's integrated into a long-term energy strategy. Research and development (R&D) has the potential to lower costs, boost efficiency, and speed up economic growth.

To make renewable energy systems more competitive, research and development can lower initial costs by decreasing material and energy requirements or by increasing the effectiveness of renewable energy output. Green finance in manufacturing companies should be aggressively promoted by environmental rules. Together with environmental elements, these regulations are divided into three categories: market-driven, voluntary, and command-control environmental regulations. The study concludes that environmental constraints of all three kinds can have a favorable effect on Chinese firms' financing of green technologies. Raikar and Adamson point out that while these rules may boost the advantages of financing for green technologies, they may also increase the cost of production for businesses. Results regarding the correlation between green financing and environmental laws vary depending on sample sizes and testing methods. Green innovation is an essential bridge between smart modernization and environmental regulations in the strategic modernization of manufacturing organizations. In other words, green innovation enables manufacturing companies to make some changes for the better while keeping all other variables constant. For industrial companies, smart improvements are more valuable when the possibility of sustainable innovation increases. Goodell and Goutte (2020) have pointed out that environmental restraints play an indirect role in the clever upgrades of industrial enterprises through green innovation. The study of Khan, S., Bangash, R., & Ullah, U. (2023) evaluates various models using the business risk metric Value at Risk (VaR) to identify the most suitable framework for the KMI-30 stock market. The results indicate that although past banking experiences may not directly influence customers, several mediating factors play a significant role in shaping their willingness to adopt RAAST (Ullah, U., Khan, J., Shah, J. A., & Baloch, R. 2023). This study explores key themes including investment behavior, the efficient market hypothesis, and stock price prediction in the context of the anticipated second wave of COVID-19 (Khalil & Ullah, 2021). Besides, moving to a green industrial structure improves the quality of the environment and promotes sustainable economic development apart from easing the transition from technology innovation to an alternative technology innovation (Ouyang, Zhuang and Sun 2019; Chen and Lee 2020).

This paper seeks to elucidate these processes in more detail, with a particular emphasis on successful policy interventions and other strategic actions that encourage green innovation. Furthermore, by fostering global collaboration and knowledge sharing, this research has the potential to catalyze collective efforts towards addressing global environmental challenges and promoting a more sustainable future for generations to come. The following part is a literature review which explained the relevant literature. The third section is methodology followed by research to collect data and measurement methods. The last section is regarding data analysis which has basic and advanced tests for results.

2. Literature Review

2.1. Green innovation

As it is today, GI is an essential tool for companies looking to grow and stay in business. Improved market positioning, customer attraction, eco-friendly service provision, and competitive advantages are all benefits of a successful GI. Because of these benefits, researchers and organizational managers are becoming interested in GI. Schumpeter's innovation theory is often cited in studies of innovation. GI satisfies consumer expectations for environmental protection, according to Tang, Fu and Boamah (2023). Entitled "green innovation" or "eco-innovation," it is characterized as a procedure that encourages the creation of innovative production techniques and technologies with the goal of reducing environmental hazards like pollution and unfavorable consequences of resource extraction (like energy) (Castellacci and Lie 2017). A significant portion of China's GDP and employment are derived from the manufacturing sector, which is essential to the country's economic growth. According to Cai and Li (2018), China has adopted policies aimed at promoting environmental sustainability through proactive measures. With the goal of achieving long-term economic growth, the government has developed policy tools to promote green innovation in the manufacturing sector. The industrial sector contributes significantly to greenhouse gas (GHG) emissions, accounting for 58.27% of all carbon emissions in China, despite playing a crucial role in the country's economy (Liu, Yang et al. 2019). To limit or prevent environmental harm, adopting efficient and effective green solutions is vital in addressing this negative impact. Because there are so many moving parts and unknowns in the process, governments and managers have found it difficult to transform industrial activities into green innovation practices (Gupta and Barua 2018). Many industries have taken steps to use innovative, environmentally friendly methods; however, in practice there is little connection between these methods and their sustainability performance (i.e., how they fare in terms of social, environmental, and economic results). In 2017, a study on This type of research was also conducted by Gupta and Barua (2017), Jiang, Hu et al. (2018), and Konys (2019).

In a separate study, Gupta and Barua (2018) devised a model to cultivate innovation in manufacturing enterprises. The research identified the factors that drive rooting for a green-tinged innovation approach, relationships between these factors, and its effects. Furthermore, Gupta and Barua (2018) listed the barriers to green innovation among SMEs and offered recommendations on how to cross them successfully. There is still a great need for further research on the implementation of green innovation in manufacturing, whether it be green technological development, green competitive advantage, green process innovation, green management innovation (Gupta and Barua 2018), ecology-based manufacturing innovation (Gupta and Barua 2018) or green supply chain innovation In relevant fields such as hardware and software of these measures in operational terms including their methods (Strategic Planning Institute, 1986), main performances (Yin, Gong and Wang 2018) or sub-processes (Qureshi et al., 2018), we are on a deeper basis as well as above-ground. This will contribute to sustainability and show how these industries can learn from one another. Empirical evidence demonstrated a positive correlation within environmental regulation and innovations in green technologies across different regions of China. The study used panel data from 30 provinces and cities between 2008 and 2017, as well as data from 45 publicly traded organizations in China's highly polluting industries. The Porter hypothesis is supported by these results (Lee and Wang 2021).

2.2. Economic Growth & Green Innovation

The connection between economic growth and environmental quality on the one hand and technological innovation on the other has received the attention of a many researchers. Technical innovation is pivotal in environmental quality; countless studies have shown. The more efficient factor allocation, for instance, will reduce the output of carbon dioxide from industry processes. This has reached a point of consensus by Hascic, de Vries et al. (2008); and Liu and Liang (2013). Chan, Yee et al. (2016) used a study of Chinese companies to explore the empirical relationship between research and development, environmental constraints, and business performance. Legislation in the field of environment seems to encourage innovation; the result is increased corporate profitability. According to Klewitz and Hansen (2014), the most effective way to maximize the utilization of existing resources, protect environmental quality and raise the living standard of the populace while ensuring that it will be borne over generations by social sustainability is through technical innovation twice over. Using cross-sectional data from 37 GEM 2002 countries, Wong et al., (2005) demonstrated a positive relationship between technical innovation and economic growth. Padilla-Pérez and Gaudin (2014) focused their major research on examining the relationship with innovation, science, and technology and environmental sustainability in Central American nations. Their findings indicate a strong correlation between technological advances and sustainable development. Du, Liu and Diao (2019) gathered information from 71 nations between 1996 and 2012 to investigate how technological innovation affects CO2 reduction. The results illustrated that if desired, these might come within reach of technical innovation to reduce CO2. Noel (2006) used data on 127 industrial businesses from 1989-2004 to assess the relationship between environmental innovation and air pollution. Their results showed that environmental innovation matters for air pollution reductions. Several literatures suggested that green innovation of economies leads to concurrent economic growth and environmental quality (sun et al., 2008). Green innovations contrast to traditional innovation with the implementation of new ideas and technology that reduce pollution aid in the efficient use of resources while maintaining economic benefits (Wu, Xue et al. 2021). Moreover, it is not only synonymous with environmental issues but seeks positive environmental outcomes. Because of this, it is often considered a pivotal strategy for generating sustainable competitive advantages (Fernando, Jabbour and Wah 2019). The heightened awareness for the environment and increasing availability of green products as well choices drive scientists to research on GI in larger numbers with an order growth in within last few decades globally. The overall traction GI research has gained in recent years reflects its growing relevance as a tool to provide environmental services that are essential for organizations and society.

2.3. Energy Consumption & Green Innovation

Well, several studies show a significant positive relationship between energy usage and green innovation in the energy sector. This appears to be a simple, but elemental core reasoning of; "the market is where innovation follows". For example, Kahouli (2018) argued that a 1% increase in electricity consumption could lead to an 8.93% rise in research and development expenditures. Wong et al has also demonstrated the same. Fossil fuel usage was becoming more critiqued prompting research and development, which stimulated consumer behavior. Conversely, research and development of renewable energy have been associated with decreased reliance on fossil fuels. However, Nissen and Williams (2016) examined the idea of decoupling and found that after utility companies adopted decoupling regulations, there was a notable rise in spending on efficiency programs and energy savings. Datta (2019) examined American electric utility companies to bolster these findings. Furthermore, Kahn-Lang (2016) documented significant drops in household electricity use linked to decoupling strategies. When it comes to economic development, the relationship between energy use and innovation is most often considered. Using a Granger causality test, Tang and Tan (2013) found that energy innovation not only indirectly affected electricity consumption in Malaysia but also was a cause of its EG. They also point out that the relationship between EG and electricity use is two-way. Much research in economics has focused on the environmental impacts of renewable and non-renewable energy sources. According to Bashir, Ma et al. (2022), who used a CS-ARDL approach, renewable energy sources decrease pollution while non-renewable sources exacerbate environmental deterioration. Similarly, He, Adebayo et al. (2021) analyzed econometric data from Uruguay to determine the impact of the two types of energy consumption on environmental outcomes from 1980 to 2018. They also utilized a dual correction methodology to analyze Mexico's environmental performance. Contrary to previous studies, they employed quantile regression to show that renewable energy usage in Uruguay is bad for the environment.

2.4. Foreign Direct Investment & Green Innovation

Over the years, educational institutions have given FDI much attention because it is an essential means for businesses to get outside funding for R&D. However, there is little data on how FDI affects the home country's gross domestic product. Three main categories may be made out of the research findings on the relationship between FDI and GI. First of all, according to certain scholars, FDI can greatly increase the GI level in home countries. Using the dynamic GMM model, Han and Wang (2016) looked into the connection between EE and foreign direct investment (FDI) in China. Their results demonstrated that reverse technology spillover from FDI somewhat increases EE. They found that both types of FDI effectively increase the GI level in home nations, irrespective of the features of the host nation. That foreign direct investment (FDI) affects GI non-linearly and a support the "uncertainty theory" is the third point of view. According to an empirical study by Hu, Qu and Dong (2016) there is some variation in the long- or short-term impacts of FDI on green total factor output. Several factors influence the direction and size of the reverse spillover effect of foreign direct investment on the home nation's gross domestic product (GDP). Many studies have examined these factors including Wang and Chen (2018) as they focused on the connection among OFDI, environmental regulations, and GI. Foreign direct investment (FDI) boosts the home country's GDP (GI) in countries with stricter environmental regulations, according to Li et al. (2016a), but the impact is smaller in countries with looser regulations. In a related vein, Nie and Wu (2020) found there was a marked single threshold effect when they used environmental regulation as the threshold variable to study whether FDI has a nonlinear relationship with regional green technology innovation capacity. In addition, FDI-led EG has received a great deal of attention as an imperative factor to drive the economic growth of any country (Sharif, Afshan et al. 2020). Foreign direct investment (FDI) is essential for EG; on the other hand, it carries more environmental risks, especially in developing countries such as Pakistan (Ur Rahman, Chongbo and Ahmad 2019).

2.5. Environmental Sustainability & Green Innovation

The relation between energy use and environmental sustainability has been inquired by scholars for nearly 50 years (Destek and Sinha 2020). Different indicators in studying the extent of environmental sustainability have been used for these studies. In recent years, there is a growing interest in using the EF as an indicator of environmental sustainability compared to Criticism with some previous studies utilizing CO2 emissions far more frequently than sulfur oxide (Nathaniel and Adeleye 2021). Green innovation (GI) is a unique form of technical change that can improve environmental performance (Yang and Wang 2019). For economies wanting to carry out GI projects, this presents a tremendous challenge with enormous capital, great risks, and a long time required for its research and development. Green technology has been rising in recent years and it is causing businesses, universities, and potentially governments to further their investment into this area to build a better landscape for green energy, which will improve efficiency as well as help tackle the climate change problem. Environmental regulations and GI programs have both played a significant role in the reduction of carbon dioxide emissions and the improvement of the environment. The widespread adoption of renewable energy sources is a key component of green innovation's ability to drastically reduce emissions of carbon dioxide and other pollutants (Ganda 2020). Green innovation has been spreading over the world due to two interconnected factors: increasing energy demand & environmental degradation. Thus, transitioning from oil and gas to alternative energy sources is not a walk in the park for many industries or companies (World Bank, 2022). Over the previous decade, renewable energy's growth has been nothing short of spectacular, consistently above projections. The proportion of renewable energy to total energy consumption has remained relatively constant despite these remarkable developments (World Bank, 2021).

2.6. R&D & Green Innovation

R&D expenditures are critical to a company's attempts at green innovation (GI), as noted by Parthasarthy and Hammond (2002). Research and development investment is widely recognized as being essential for promoting EG and increasing company value, as mentioned by (Ghisetti and Pontoni 2015). The main goal of R&D spending is to promote innovation, which raises revenue for the business. Therefore, as Wakelin (2001) discusses, increased R&D investment can make clean technologies more favorable and have a major impact on the firm's productivity development by facilitating the adoption and implementation of GI. On the one hand, expenditures in research and development (R&D) for green technologies are linked to inherent risks and uncertainties (Alam, Uddin et al. 2020), which may result in overinvestment and insufficient returns to cover incurred costs (Guo and Minier 2021). Businesses frequently face significant expenses with unclear future prospects, and the time lag between expenditures in green technology research and development and the achievement of novel results can negatively affect the company's present financial performance (Martin, Wiseman and Gomez-Mejia 2016). However, managers may prioritize immediate benefits above future technical advances, which could lead to a reduction in green technology R&D spending and an increase in risk aversion (Martin, Wiseman and Gomez-Mejia 2016). Research and development investments in sustainable technologies and innovative energy sources may have a negative effect on budgets in the near term, but they pay off in the long run (Leung and Sharma 2021). In addition, there is an optimal value for research and development investments in green technology, and some studies have confirmed the presence of a nonlinear relationship between technical innovation and corporate success.

2.7. Financial development & Green innovation

On the other hand, financial development promotes technological advancement, modernizes distribution channels and production techniques, and obtains necessary funding for investments with various sources of capital. This underscores the importance of combining financial development with green innovation in order to promote long-term environmental sustainability. In terms of this interaction, financial development has never missed an opportunity to deal creatively with its impact on environmental objectives. Reports by Abid (2017) and Baloch, (Zhang et al. 2019) contend that financial development exacerbates the pace of environmental degradation. This article represents an attempt to make two points based on the discussion of the previous one. One point is that different countries' responses to global environmental problems (which are developmentally rooted and more pressing for those countries in the tropical and subtropical zones than they are temperate) can affect where they stand in order to meet long-term sustainability goals (Ganda 2020). Furthermore, the results of research carried out by Sodeyfi and Katircioglu (2016) draw attention to a sturdy correlation between financial development and general EG. To further complicate matters, Ozturk and Acaravci (2013) state that environmental goals have little effect on financial progress. A more concentrated analysis of China's financial development and found evidence that it positively affects environmental quality, particularly in terms of improved management practices.

2.8. Environmental Regulation & Green innovation

The environmental legislation of the governments can significantly affect the highly polluting firms and their stock returns (Guo, Zhou et al. 2021). As pointed out by Gupta and Barua (2018), companies must therefore ensure that they achieve high levels of environmental performance to deal with the regulatory issues, address environmental issues and avoid getting into trouble. Lambertini et al. (2017) have pointed out that in industries that pollute during the manufacturing process, green innovation has an inverted U-shape relationship with competition. Han and Wang (2016) compared the GIE in each of the regions of China between 2005 and 2010 and found that the Eastern region had a higher GIE than the other regions. Due to ecological externalities and the common pool character of environmental resources, market forces may not be adequate to support sustainable economic development. Thus, there is a need to come up with reasonable environmental regulation policies. These regulations aim at effectively solving environmental and energy issues. Two theoretical models that explain the impact of environmental regulations on innovation are available. Gollop and Roberts (1983) have defined the “restriction hypothesis” as the view that technological advance is limited by environmental factors. From one perspective, there is a belief that environmental regulations can motivate companies to look for green innovation (Hu, Qu and Dong 2016). On the other hand, another stream of literature reveals that environmental regulation and green innovation have a negative relationship or a U-shape (Li, Zhang et al. 2022). Compliance with environmental regulations may lead to significant investments in structures that may, in turn, lead to a possible drain of cash on green innovation activities, thus reducing the overall level of green innovation activities. This kind of innovation is highly beneficial in resource conservation, pollution control, and efficient recycling of waste streams and raw materials (Li, Zhang et al. 2022). For instance, green technology innovation enhances objectives such as environmental conservation, EE, and emissions cut while enhancing corporate efficiency and competitiveness (van der Linde 1995). However, in a free-market economy, there is usually not enough technological advancement in environmental conservation. noted that market failures arising from the two externalities associated with green technology innovation often caused inefficient investment in this area. Therefore, the advancement of green technology innovation requires government interferences such as environmental policies (Hu, Qu and Dong 2016)

2.9. Control Variables

The understanding of this is necessary as green innovation is very important for sustainable development (Kunapatarawong and Martínez-Ros 2016) and also shows the ability to be supported by other industries in relation to their digital economy. The new economy model, which is the digital economy, as pointed out by Dai, Fan et al. (2022) brings about a pronounced role in green innovation. As found by Li and Chen (2019), innovating in the digital economy can greatly enhance the performance of the regional ecological economy. In addition, digital finance can stimulate green innovations by increasing R&D funding and eliminating the constraints in funding (Li and Chen 2019). Moreover, green innovation helps companies relieve their social commitments and increase competitiveness besides improving environmental performance. Green innovation increases the rate at which a country can develop, as well as the quality of its EG. Studies have shown that developed countries generally allocate more resources for innovation (Du et al., 2019) and spend higher R&D project expenditure with a large portion of them devoted to the employment of an intricate baseline in the form of the supply chain, making it possible to help evolutionary track for green innovations within work-design processes (Yang, Gao et al. 2021). Besides, it is also implied that countries with a high level of export and FDI are more likely to have strong economics (Yang, Gao et al. 2021). This is a conducive environment for financing R&D and green innovation, which increases the efficiency of these measures. Scholars also note the importance of pricing, intensity, and timing for guiding green innovation (Hille et al., 2020). Urbanization is the movement of individuals into and out of urban areas, as well as the expansion within those hallmark regions (Luo et al., 2018). In this scenario, it worsens human health and leads to decreases in living conditions and sanitary life of both urban and rural people (Ahmad and Raza 2020). The question raised by urbanization's consequences is no question of great urgency. Technological advance is fundamentally one of the main factors propelling this new round of urbanization (Liu and Dong 2021). It is necessary to speed up technical innovation so as to support sustainable urban development. Urbanization boosts the innovation of technology by promoting the integration of production factors, boosting effective demand, and speeding up the centralization of production factors.

3. Research Methodology

3.1. Variables Description

Green innovation is crucial for protecting the environment and is important for both organizations and communities. Research in this area has increased lately. Pollution threatens human survival, so many are turning to green innovation for sustainability and EG (Severo, de Guimarães and Dorion 2017). Companies are using green innovation to grow and stay competitive. It attracts customers and offers eco-friendly services (Liu and Dong 2021). However, appropriately operating institutions are required to achieve green EG (Ahmad and Raza 2020). According to seminal publications by Williamson (1989) and North (1990), institutional quality continues to be one of the most important drivers of EG. A definition of FDI is a financial investment in a company based outside of the investor's home country that the investor intends to hold for the long term. By considering the causes and effects of various spatial characteristics, such to be soil type, cover as well as thickness, water- and nutrient-holding capacity, and slope, planners and farmers can select the most sustainable management techniques for each farm, ensuring the long-term viability of the cropping system (Khan, Chenggang et al. 2021). Sustainability refers to the relationship between the environment, society, and economics. According to definitions, sustainable farming must ensure stable and secure food production for an ever-increasing population (Khan et al., 2023).

Developing new products and making sure they sell well is what development is all about (Kainulainen, 2014). In general, research and development refer to deliberate attempts to extend knowledge and utilize that information in the creation of new items, procedures, or services. In modern times, innovation initiatives are also intimately associated with the concept of research and development. According to Kauinulainen (2014), scientific discovery comprises a wide variety of activities, through basic study through the (successful) promotion of a good or the (efficient) execution of a new procedure.

3.2. Other Variables

The financial department promotes EG through capital accumulation and technical progress. Financial development as both a consequence of EG and forcing factor. It also eases poverty and inequality by giving the poor and vulnerable populations more chances to borrow finance at lower risk-cost, limits their exposure to shocks while simplifying risk management, stimulates industrial investment (which raises incomes) and productivity increases that come with it (Maimbo and Melecky 2016). This research examines the relation and role of mediating variable financial development between independent variables, EG, renewable energy consumption, R&D, foreign direct investment, Environmental sustainability, and dependent variable green innovation. The proxy for the mediating variable is % of GDP previously used by Wang, Hu, et al., (2024). The research examines the role and checks the relationship of moderator variable environmental regulation in between financial development and green innovation. The proxy for the moderator variable environmental regulation is GDP per capita (current US$) Previously used by Zou & Wang, (2024).

3.3. Control Variables

Additionally, as digital finance helps businesses overcome funding challenges, digitization increases the production scale and flexibility of businesses (Wang and Chen 2018). The research used control variables trade openness (TO), Urbanization (URB) Digitization (DIG) to ensure the results are significant and reliable. Trade openness is measured by Trade of goods and services (%

of GDP) (Wang, Zhang, et al., 2024). However, Urbanization is measured by Urban population (% of total population) (Wang, Zhang, et al., 2024). Digitalization measured by Mobile cellular subscriptions (Li et al., 2024).

3.4. Empirical Model

This model shows how EG, foreign direct investment, renewable energy consumption, environmental sustainability, and R&D affect green innovation. Equations 2 and 3 extend Equation 1 by incorporating the mediation of financial development and control variables. The model is adapted from Zang et al. (2021) and expanded.

$$GI = f\ (EG, REC, FDI, ES, R\&D) \qquad (1)$$

The above function implies that EG, foreign direct investment, renewable energy consumption, environmental sustainability, and R&D on green innovation.

$$GI_{it} = \beta_0 + \beta_1\ EG_{it} + \beta_2\ REC_{it} + \beta_3\ FDI_{it} + \beta_4\ ES_{it} + \beta_5 R\&D_{it} + \mu_i + \epsilon_{it} \ldots \qquad (2)$$

Where I and t stand for individual nation and eras, respectively. The erroneous term is (εit). β is the vector for independent variables. EG indicates EG and REC indicates renewable energy consumption, FDI indicates the Foreign direct investment and ES indicates environmental sustainability.

$$GI_{it} = \beta_0 + \beta_1 EG_{it} + \beta_2\ REC_{it} + \beta_3\ FDI_{it} + \beta_4\ ES_{it} + \beta_5\ R\&D_{it} + \mu_{it}.\ MV_{it}\partial_1\ ER_{it} + \mu_{it} \qquad (3)$$

This model shows the impact of EG, foreign direct investment, renewable energy consumption, environmental sustainability, and R&D, financial development used as mediator and environmental regulation as a moderator variable. Where M represents the mediator and moderator variables.

$$GI_{it} = \beta_0 + \beta_1 EG_{it} + \beta_2 REC_{it} + \beta_3 FDI_{it} + \beta_4 ES_{it} + \beta_5 R\&D_{it} + MV_{it}\partial_1 ED_{it} + \mu_{it} + C_1 TO_{it} + C_2 URB_{it} + C_3 DIG_{it} + \mu_{it} \qquad (4)$$

TO represents trade openness and URB can be abbreviated by urbanization and D represents digitalization. The i and t subscripts, which we previously used for time series and cross-sectional data, respectively, are used to indicate panel data. This is because time series and cross-sectional dimensions are present in panel data (Asteriou & Hall, 2015).

4. Analysis and Discussion

The detailed analysis is given below:

4.1. Descriptive Statistics

Table 4.1: *Descriptive Statistics*

Variable	Obs	Mean	Std. Dev.	Min	Max
GI	1127	5.091	2.013	.009	7.903
EG	1127	9.158	1.317	5.825	11.486
RD	1127	6.219	2.214	0	12.726
REC	1127	2.179	1.847	-4.605	6.5
FDI	1127	3.797	7.998	0	104.82
ES	1127	5.998	5.924	.055	31.274
FD	1127	4.364	.761	2.062	6.131
ER	1127	9.104	1.422	4.921	11.552
DIG	1127	15.812	2.305	0	20.885
URB	1127	4.124	.441	2.595	4.605
TO	1127	3.68	.734	1.633	5.434

The dataset, with 1,127 observations, examines factors influencing green innovation (GI). The dependent variable, GI, has a mean of 5.091, a standard deviation of 2.013, and ranges from 0.009 to 7.903, indicating moderate variability. Key independent variables include economic growth (EG), with a consistent mean of 9.158, and research and development (RD), showing significant variation with a mean of 6.219. Energy consumption (REC) has a mean of 2.179, with some negative values suggesting reductions or errors. Foreign direct investment (FDI) displays high variability, with a mean of 3.797, while environmental sustainability (ES) shows substantial differences with a mean of 5.998. Financial development (FD) is relatively consistent, with a mean of 4.364, whereas environmental regulations (ER) and digitalization (DIG) vary significantly. Urbanization (URB) remains stable, with a mean of 4.124, while trade openness (TO) indicates variability with a mean of 3.68. Overall, the dataset provides a comprehensive overview of economic, environmental, and developmental factors affecting green innovation.

4.2. Correlation

The dataset explores relationships between green innovation (GI) and various independent variables, revealing key correlations. GI has a slight positive correlation with economic growth (EG) (0.169), research and development (RD) (0.161), financial development (FD) (0.111), environmental sustainability (ES) (0.075), and environmental regulation (ER) (0.073). Conversely, energy consumption (REC) shows a weak negative correlation with GI (-0.039), while foreign direct investment (FDI) has no significant correlation (-0.003).

Table 4.2: *Correlation Results*

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GI	1.000							
(2) EG	0.169	1.000						
(3) REC	-0.039	-0.192	1.000					
(4) RD	0.161	0.199	-0.146	1.000				
(5) FDI	-0.003	0.320	-0.148	-0.013	1.000			
(6) ES	0.075	0.583	-0.366	0.189	0.082	1.000		
(7) FD	0.111	0.457	-0.276	0.209	0.247	0.173	1.000	
(8) ER	0.073	0.918	-0.220	0.147	0.305	0.531	0.475	1.000

Among independent variables, EG strongly correlates with ER (0.918) and ES (0.583), and moderately with FD (0.457) and FDI (0.320). REC is negatively correlated with ES (-0.366) and FD (-0.276), while RD positively correlates with FD (0.209) and ES (0.189), highlighting R&D's role in enhancing financial systems and sustainability.

4.3. VIF

Table 4.3: *VIF*

	VIF	1/VIF
EG	7.429	.135
ER	6.646	.15
ES	1.824	.548
FD	1.454	.688
REC	1.284	.779
FDI	1.176	.85
RD	1.103	.907
Mean VIF	2.988	.

The Variance Inflation Factor (VIF) analysis indicates moderate to high multicollinearity for economic development (EG) and environmental regulation (ER), with VIFs of 7.429 and 6.646, respectively, reflecting their strong correlation (0.918). Other variables, including environmental sustainability (ES), financial development (FD), energy consumption (REC), foreign direct investment (FDI), and research and development (RD), have low VIFs below 2, suggesting minimal multicollinearity concerns. The mean VIF of 2.988 indicates that the overall model has low multicollinearity, but the high VIFs for EG and ER warrant further examination to ensure accurate regression estimates.

4.4. Brusch Pagan Test

Table 4.5: *Brusch Pagan Test*

Component	*Variance (Var)*	*Standard Deviation (sd = sqrt(Var))*
GI	4.052897	2.013181
E	1.605071	1.266914
U	2.385855	1.544621
Test	Value	
chibar2(01)	3738.38	

If heteroscedasticity is present in the regression model, the Brusch-Pagan test results will shed light on it. With a standard deviation of 2.013181, the variable, green innovation (GI), has a variance of 4.052897. There is a standard deviation of 1.544621 and a variance of 2.385855 for the individual-specific error term, and a variance of 1.605071 for the residuals (e). There is statistical significance as shown by the chi-square test's statistic (chibar2(01)) of 3738.38. A high chi-square value indicates that the model has substantial heteroscedasticity, providing strong evidence for the null hypothesis of homoscedasticity. The inference made from the model and the efficiency of the coefficient estimations may be compromised if the variability in the the residuals is not constant across data. Hence, to handle this heteroscedasticity in the assessment, robust standard errors or other remedial procedures may be required (Brusch & Pagan, 1979; Greene, 2003).

4.5. Slope Homogeneity Test

Both the unadjusted and adjusted Delta statistics have p-values of 0.000: 16.213 and 20.781, respectively. They are both very significant, with p-values of 0.000. According to Brusch and Pagan (1980) and Pesaran and Yamagata (2008), this finding suggests that the independent variables' effects on green innovation change between units. To account for these differences, a model that accounts for slope heterogeneity could be better suitable.

Table 4.6: *Slope Homogeneity Test*

	Delta	p-value
	16.213	0.000
adj.	20.781	0.000

Both the unadjusted and adjusted Delta statistics have p-values of 0.000: 16.213 and 20.781, respectively. They are both very significant, with p-values of 0.000. This highly significant finding disproves the premise of slope homogeneity, which states that the regression coefficients' slopes are identical across all units or groups. Put simply, the way the independent factors are related to the dependent factor (green innovation) varies significantly among the dataset groups.

4.6. Cross sectional dependency Test

Table 4.7: *CD Test Results*

Variable	***CD-test***	***p-value***	***Average Joint T***	***Mean ρ***	***Mean abs(ρ)***
GI	-0.62	0.535	23	0	0.43
EG	79.844	0	23	0.49	0.68
REC	23.144	0	23	0.14	0.5
RD	6.374	0	23	0.04	0.3
FDI	7.306	0	23	0.04	0.22
ES	5.259	0	23	0.03	0.57
FD	49.408	0	23	0.3	0.42
ER	127.085	0	23	0.77	0.78

The CD-test for green innovation (GI) shows no significant cross-sectional dependence, with a statistic of -0.62 and a p-value of 0.535. However, the independent variables, including economic growth (EG), energy consumption (REC), and others, exhibit strong cross-sectional dependence, with highly significant CD-test statistics and p-values of 0. The Average Joint T statistic of 23 and Mean ρ values (0.03 to 0.77) confirm substantial dependencies, particularly for environmental regulation (ER). While GI shows no significant dependence, the interrelated nature of the independent variables suggests that assumptions of independence may not hold, potentially affecting model robustness.

4.7. Stationarity Test

Table 4.8: *2nd Generation Unit Root Test*

	CIPS		***CADF***	
Variables	***Level***	***1st diff***	***level***	***1st Diff***
GI	/	-4.441		-4.441
EG	/	-3.375	/	-3.375
R & D	-2.342	/	-2.342	/
REC	/	-4.136	/	-4.136
FDI	-3.528	/	-3.528	/
ES	/	-4.291	/	-4.291
FD	-2.419	/	/	-2.419
ER	/	-3.59		-3.59

The CADF (Cross-sectional Augmented Dickey-Fuller) test results indicate the stationarity properties of variables related to green innovation (GI) and its independent factors. In the "level" column, research and development (R&D), financial development (FD), and foreign direct investment (FDI) exhibit stationarity, with CADF test statistics of -2.342, -2.419, and -3.528, respectively. This suggests these variables do not show a stochastic trend in their original forms. In contrast, variables of green innovation (GI), economic growth (EG), energy consumption (REC), environmental sustainability (ES), and environmental regulation have stationary in the first difference column with CADF statistics between -3.375 to -4.441. This means they can be analyzed robustly for time series and in terms of econometric modeling after removing any trends or drifts from these variables. These benchmarks are critical for maintaining the high fidelity of statistical inferences and models involving these variables by researchers or policy analysts.

4.8. Fixed Effect

Table 4.9: *Fixed Effect Results*

GI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
EG	.092	.321	0.29	.775	-.538	.721	
RD	-.038	.041	-0.93	.354	-.12	.043	
REC	-.077	.042	-1.83	.067	-.16	.005	*
FDI	.001	.007	0.12	.906	-.012	.014	
ES	.004	.018	0.20	.842	-.032	.04	
FD	-.088	.087	-1.00	.316	-.26	.084	
ER	-.067	.156	-0.43	.67	-.373	.24	
Constant	-.452	4.207	-0.11	.915	-8.706	7.802	

Mean dependent var	5.091	SD dependent var	2.013
R-squared	0.025	Number of obs	1127
F-test	2.718	Prob > F	0.000
Akaike crit. (AIC)	3675.692	Bayesian crit. (BIC)	3730.993

**** p<.01, ** p<.05, * p<.1*

The fixed effects regression analysis reveals that green innovation (GI) is significantly related to economic growth in R1 but insignificantly associated with research and development, energy consumption, foreign direct investment, environmental regulation, financial development, or environmental sustainability, the independent variables. GI is not significantly affected by EG (coefficient = 0.092, p = 0.775), RD (coefficient = -0.038, p = 0.041), REC (coefficient = -0.077, p = 0.067), and FDI. Their model explains virtually none of the variability in GI, with an R-square value of 0.025. Nonetheless, the model as a whole is highly significant (F test: p < 0.000), indicating that even though no individual variable in itself matters, there are enough ‘real effects’ amongst all variables explaining the variation of GI.

4.9. Random Effect Model

Table 4.10: *Random Effect Model Results*

GI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
EG	.092	.321	0.29	.775	-.538	.721	
RD	-.038	.041	-0.93	.354	-.12	.043	
REC	-.077	.042	-1.83	.067	-.16	.005	*
FDI	.001	.007	0.12	.906	-.012	.014	
ES	.004	.018	0.20	.842	-.032	.04	
FD	-.088	.087	-1.00	.316	-.26	.084	
ER	-.067	.156	-0.43	.67	-.373	.24	
Constant	-.452	4.207	-0.11	.915	-8.706	7.802	
Mean dependent var		5.091	SD dependent var			2.013	
R-squared		0.025	Number of obs			1127	
F-test		2.718	Prob > F			0.000	
Akaike crit. (AIC)		3675.692	Bayesian crit. (BIC)			3730.993	

**** p<.01, ** p<.05, * p<.1*

The random effects model reveals no significant relationship between green innovation (GI) and most independent variables. Economic growth (EG) (coefficient = 0.19, p = 0.424), research and development (RD) (coefficient = -0.013, p = 0.742), energy consumption (REC), foreign direct investment (FDI) (coefficient = 0, p = 0.972), environmental sustainability (coefficient = -0.001, p = 0.941), financial development (FD) (coefficient = -0.06, p = 0.483), and environmental regulation (ER) (coefficient = -0.06, p = 0.314) all show no statistically significant impact on GI. The model's R-squared value of 0.023 indicates it explains only a small fraction of GI's variance. While the overall model is statistically significant (Chi-square = 24.874, p = 0.006), the individual coefficients do not meet common significance thresholds, warranting caution in interpreting the results.

4.10. Hausman Test

Table 4.10: *Hausman Test Results*

	Coef.
Chi-square test value	17.883
P-value	.057

With a p-value of 0.057, the Hausman test statistic is 17.883. The fixed effects model adjusts for individual-specific impacts by differing out these effects. In contrast, the random effects model implies that the individual-specific effects do not correlate with the explanatory variables. The test compares the estimates from both models. The test result is not statistically significant at the more stringent threshold of 0.01 but is slightly substantial at the standard significance threshold of 0.05 (p-value = 0.057). This shows that there is some proof that the theory of random effects isn't right because the explanatory variables and the impact on individuals might be correlated.

4.11. GMM without Mediation

Table 4.11: *GMM without Mediation Results*

GI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L	.904	.014	66.41	0	.878	.931	***
EG	.146	.02	7.37	0	.107	.184	***
RD	.025	.003	9.65	0	.02	.03	***
REC	.018	.008	2.09	.036	.034	.001	**
FDI	-.009	0	-25.75	0	-.008	-.01	***
ES	.006	.003	2.15	.032	0	.011	**
Mean dependent var		5.087	SD dependent var			2.018	
Number of obs		1029	Chi-square			.	

*** *p<.01, *** *p<.05, ** *p<.1*

In a dynamic panel data framework, the GMM (Generalized Method of Moments) study examines the link between green innovation (GI) and other important independent factors. A highly positive impact on GI (t-value = 66.41, p < 0.01) is suggested by the coefficient of the lagged dependent variable (L) being 0.904 with a standard error of 0.014, which implies that there is great persistence in green innovation across time. At the 1% level of significance (t-value = 7.37, p < 0.01), economic growth (EG) stands out among the variables that are independent with a coefficient of 0.146 and a standard error of 0.020. This suggests that there is a strong correlation between higher EG and enhanced green innovation. Likewise, RD shows a coefficient of 0.025 with a standard error of 0.003, which is likewise very significant (t-value = 9.65, p < 0.01), indicating that investments in RD help improve green innovation. A small positive link between energy consumption (REC) and green innovation is shown by a coefficient of effect of 0.018 with a standard error of 0.008, which is statistically significant on the 5% level (t-value = 2.09, p = 0.036). The opposite is true for foreign direct investment (FDI), which indicates that increased levels of FDI can impede green innovation initiatives with a highly significant negative coefficient of -0.009 (t-value = -25.75, p < 0.01). The coefficient for environmental sustainability (ES) is 0.006, with a standard error of 0.003. This association is statistically significant on the level of five percent (t-value = 2.15, p = 0.032), portentous that there is a positive relationship among GI and environmental sustainability measures. When it comes to evaluating the validity of the model, the chi-square test backs up the overall model fit. According to these findings, green innovation activities might be greatly improved by policies that promote EG, R&D, FDI, and environmental sustainability, all of which would have a favorable impact on meeting sustainable development goals.

4.12. GMM with Mediation

Table 4.12: *GMM with Mediation Results*

GI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L	.897	.016	56.51	0	.866	.928	***
EG	.139	.02	6.95	0	.1	.178	***
RD	.023	.005	5.00	0	.014	.033	***
REC	.028	.006	4.62	0	.039	.016	***
FDI	-.009	0	-26.95	0	-.009	-.01	***
ES	.007	.003	2.60	.009	.002	.011	***
FD	**.01**	**.022**	**0.44**	**.661**	**.033**	**.053**	
Mean dependent var		5.087	SD dependent var			2.018	
Number of obs		1029	Chi-square			.	

*** *p<.01*, ** *p<.05*, * *p<.1*

The Generalized Method of Moments (GMM) analysis reveals that past levels of green innovation (GI), economic growth (EG), research and development (RD), energy consumption (REC), and environmental sustainability (ES) significantly influence current GI. Lagged GI shows strong persistence (coefficient = 0.897, p < 0.01), while EG (coefficient = 0.139, p < 0.01), RD (coefficient = 0.023, p < 0.01), and REC (coefficient = 0.028, p < 0.01) positively impact GI. On the other hand, Foreign Direct Investment (FDI) has a negative impact on GI (coefficient = -0.009, p < 0.01). Additionally, a positive correlation of ES with GI is also observed (coefficient = 0.007, p = 0.009). Second, financial development (FD) does not have a direct effect on GI. These results highlight the importance of EG, RD investments, and environmental sustainability policies to encourage green innovation.

4.13. Moderation Results

Table 4.13: *Moderation Results*

GI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L	.935	.004	246.31	0	.928	.942	***
ER_FD	.002	.001	3.36	.001	.003	.001	***
Mean dependent var		5.087	SD dependent var			2.018	
Number of obs		1029	Chi-square			.	

*** *p<.01*, ** *p<.05*, * *p<.1*

Results reveal that the higher the green innovation (GI) in the past, the more current GI will be, with a reliance of 0.935 and a significance level of <1%. Moreover, the role of interaction terms between financial development (FD) and environmental regulation (ER), ER_FD, has a significant positive impact on GI (coefficient = 0.002, p < 0.01). In other words, efficient environmental regulation strengthens the positive effect of financial development on green innovation. They underline the need for sturdy regulatory regimes alongside finance systems to allow sustainable economic developments and innovation.

4.14. Discussion

Firstly, it is crucial in mapping out the geography of the impacts of green innovation on air pollution. Renewable energy green innovation has a significantly negative direct and indirect impact on air pollution. The utilization of renewable power decreases particulate emissions locally, and its spatial spillovers are found throughout other regions, indicating that green innovation exhibits geographic externality. Though fossil fuels were found to drive local air pollution significantly, the study urges that renewable energy must receive better funding as it performs well in scenarios where this is a key goal. Secondly, a long-term relationship between renewable energy consumption and environmental sustainability provided, confirming short and long-term results. Therefore, based on the synthesis of the above studies and your research, it is evident that the development of green innovation for sustainable development requires policy and strategic investment. The policy interventions should develop competitive green innovation markets, encourage technology transfers through FDI, redress regional imbalances, and align economic incentives with institutional sustainability objectives. In this way, societies can obtain the greatest possible positive impact of green innovation on the environment and the economy in the long term.

5. Conclusion & Implications

This study concludes that green innovation in 50 countries is influenced by a complex interplay of economic growth, R&D investment, energy consumption patterns, and the nature of foreign direct investment (FDI). While economic growth and targeted R&D funding positively drive green innovation, the effect of FDI is nuanced—indicating that not all FDI supports sustainable development and its alignment with green objectives must be carefully evaluated. A key limitation of the study lies in its generalization across diverse national contexts, potentially overlooking country-specific dynamics, institutional quality, and sectoral variations in innovation capacity. Practically, the findings underscore the need for comprehensive, targeted policies such as R&D grants, green tax incentives, and renewable energy subsidies. Governments and private sectors are encouraged to support innovation ecosystems—like sustainability-focused clusters and research labs—while ensuring financial instruments such as green bonds and sustainable loans are accessible. Future research should explore sector-specific impacts of FDI, longitudinal analyses of policy interventions, and the role of public-private partnerships (PPPs) in enhancing green innovation, especially in low- and middle-income countries striving for sustainable development.

Conflict of Interest

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References

Abid, M. (2017). "Does economic, financial and institutional developments matter for environmental quality? A comparative analysis of EU and MEA countries." *Journal of Environmental Management*, *188*, 183-194.

Ahmad, M. and M. Y. Raza (2020). "Role of public-private partnerships investment in energy and technological innovations in driving climate change: evidence from Brazil." *Environmental Science and Pollution Research, 27*, 30638-30648.

Alam, A., et al. (2020). "R&D investment, firm performance and moderating role of system and safeguard: Evidence from emerging markets." *Journal of Business Research, 106*, 94-105.

Baloch, M. A., et al. (2019). "The effect of financial development on ecological footprint in BRI countries: evidence from panel data estimation." *Environmental Science and Pollution Research*, *26*, 6199-6208.

Cai, W. and G. Li (2018). "The drivers of eco-innovation and its impact on performance: Evidence from China." *Journal of Cleaner Production*, *176*, 110-118.

Castellacci, F. and C. M. Lie (2017). "A taxonomy of green innovators: Empirical evidence from South Korea." *Journal of Cleaner Production, 143*, 1036-1047.

Chan, H. K., et al. (2016). "The moderating effect of environmental dynamism on green product innovation and performance." *International journal of production economics*, *181*, 384-391.

Chen, Y. and C.-C. Lee (2020). "Does technological innovation reduce CO2 emissions? Cross-country evidence." *Journal of Cleaner Production*, *263*, 121550.

Dai, D., et al. (2022). "Digital economy, R&D investment, and regional green innovation—analysis based on provincial panel data in China." *Sustainability*, *14*(11), 6508.

Datta, S. (2019). "Decoupling and demand-side management: Evidence from the US electric industry." *Energy Policy, 132*, 175-184.

Destek, M. A. and A. Sinha (2020). "Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from organisation for economic Co-operation and development countries." *Journal of Cleaner Production*, *242*, 118537.

Du, J.-l., et al. (2019). "Assessing regional differences in green innovation efficiency of industrial enterprises in China." *International Journal of Environmental Research and Public Health, 16*(6), 940.

Fernando, Y., et al. (2019). "Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: does service capability matter?" *Resources, conservation and recycling, 141*, 8-20.

Fliaster, A. and M. Kolloch (2017). "Implementation of green innovations–The impact of stakeholders and their network relations." *R&d Management*, *47*(5), 689-700.

Ganda, F. (2018). "The influence of green energy investments on environmental quality in OECD countries." *Environmental Quality Management*, *28*(2), 17-29.

Ganda, F. (2020). "The influence of corruption on environmental sustainability in the developing economies of Southern Africa." *Heliyon, 6*(7).

Ghisetti, C. and F. Pontoni (2015). "Investigating policy and R&D effects on environmental innovation: A meta-analysis." *Ecological Economics, 118*, 57-66.

Guo, H. and J. Minier (2021). "Borders, geography, and economic activity: The case of China." *Regional Science and Urban Economics*, *90*, 103700.

Gupta, H. and M. K. Barua (2017). "Supplier selection among SMEs on the basis of their green innovation ability using Bwm and fuzzy Topsis." *Journal of Cleaner Production*, *152*, 242-258.

Gupta, H. and M. K. Barua (2018). "A framework to overcome barriers to green innovation in SMEs using BWM and Fuzzy Topsis." *Science of the total environment, 633*, 122-139.

Han, Y. and L. Wang (2016). "The effect of Ofdi reverse technology spillover on China energy efficiency." *On Econ Probl, 3*, 95-101.

Hao, Y. and P. Chen (2023). "Do renewable energy consumption and green innovation help to curb CO2 emissions? Evidence from E7 countries." *Environmental Science and Pollution Research International, 30*(8), 21115.

Hascic, I., et al. (2008). "Effects of environmental policy on the type of innovation: the case of automotive emissions control technologies." *Oecd Journal: Economic Studies*, *2009*(1): 49-66.

He, X., et al. (2021). "Consumption-based carbon emissions in Mexico: an analysis using the dual adjustment approach." *Sustainable Production and Consumption, 27*, 947-957.

Hu, Y., et al. (2016). "The effect of green productivity growth of China's Fdi: An empirical analysis based on the perspective of spatiotemporal heterogeneity." *Economist*, *12*(8).

Hur, W. M., et al. (2013). "Assessing the effects of perceived value and satisfaction on customer loyalty: a 'green'perspective." *Corporate social responsibility and environmental management*, *20*(3), 146-156.

Jiang, P., et al. (2018). "Green supplier selection for sustainable development of the automotive industry using grey decision-making." *Sustainable Development*, *26*(6), 890-903.

Kahn-Lang, J. (2016). "Effects of Electric Utility Decoupling on Energy Efficiency." *The Energy Journal,* 37(4), 297-314.

Khalil, M. S., & Ullah, U. (2021). Effect of Covid-19 on financial markets: Evidence from Pakistan, India and Italy. *Journal of Business & Tourism*, *6*(2), 1–10. https://doi.org/10.34260/jbt.v6i2.150

Khan, A., et al. (2021). "Impact of technological innovation, financial development and foreign direct investment on renewable energy, non-renewable energy and the environment in belt & Road Initiative countries." *Renewable Energy*, *171*, 479-491.

Khan, S., Bangash, R., & Ullah, U. (2023). Unlocking market insights and AI-driven stock return analysis of the KMI-30 index. *Journal of Asian Development Studies, 12*(3).

Klewitz, J. and E. G. Hansen (2014). "Sustainability-oriented innovation of SMEs: a systematic review." *Journal of Cleaner Production*, 65, 57-75.

Konys, A. (2019). "Green supplier selection criteria: From a literature review to a comprehensive knowledge base." *Sustainability, 11*(15), 4208.

Kunapatarawong, R. and E. Martínez-Ros (2016). "Towards green growth: how does green innovation affect employment?" *Research Policy, 45*(6), 1218-1232.

Leung, T. Y. and P. Sharma (2021). "Differences in the impact of R&D intensity and R&D internationalization on firm performance–Mediating role of innovation performance." *Journal of Business Research*, *131*, 81-91.

Li, G., et al. (2022). "Digital finance and sustainable development: Evidence from environmental inequality in China." *Business Strategy and the Environment*, *31*(7), 3574-3594.

Liu, H. and D. Liang (2013). "A review of clean energy innovation and technology transfer in China." *Renewable and sustainable energy Reviews*, *18*, 486-498.

Liu, J., et al. (2019). "Analysis of CO2 emissions in China's manufacturing industry based on extended logarithmic mean division index decomposition." *Sustainability, 11*(1), 226.

Liu, Y. and F. Dong (2021). "How technological innovation impacts urban green economy efficiency in emerging economies: A case study of 278 Chinese cities." *Resources, conservation and recycling*, *169*, 105534.

Maimbo, S. M. and M. Melecky (2016). "Financial policy in practice: Benchmarking financial sector strategies around the world." *Emerging Markets Finance and Trade*, *52*(1), 204-222.

Martin, G. P., et al. (2016). "Going short-term or long-term? CEO stock options and temporal orientation in the presence of slack." *Strategic Management Journal*, *37*(12), 2463-2480.

Nathaniel, S. P. and N. Adeleye (2021). "Environmental preservation amidst carbon emissions, energy consumption, and urbanization in selected African countries: implication for sustainability." *Journal of Cleaner Production 285,* 125409.

Nie, H. and Q. Wu (2020). "Does the reverse green technology spillover effect of Fdi really exist?" *Modern Manag 40*, 7-11.

Nissen, W. and S. Williams (2016). "The link between decoupling and success in utility-led energy efficiency." *The Electricity Journal*, *29*(2), 59-65.

Noel, K. T. (2006). Biophysical and Anthropogenic Influences on Elk Distribution in a Rapidly Developing Landscape in Southwestern Alberta, University of Calgary, Faculty of *Environmental Design (Environmental* ….

Ouyang, X., et al. (2019). "Haze, health, and income: An integrated model for willingness to pay for haze mitigation in Shanghai, China." *Energy Economics 84*, 104535.

Ozturk, I. and A. Acaravci (2013). "The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey." *Energy Economics*, *36*, 262-267.

Padilla-Pérez, R. and Y. Gaudin (2014). "Science, technology and innovation policies in small and developing economies: The case of Central America." *Research Policy*, *43*(4), 749-759.

Parthasarthy, R. and J. Hammond (2002). "Product innovation input and outcome: moderating effects of the innovation process." *Journal of engineering and technology management*, *19*(1), 75-91.

Severo, E. A., et al. (2017). "Cleaner production and environmental management as sustainable product innovation antecedents: A survey in Brazilian industries." *Journal of Cleaner Production*, *142*, 87-97.

Sharif, A., et al. (2020). "The role of tourism, transportation and globalization in testing environmental Kuznets curve in Malaysia: new insights from quantile Ardl approach." *Environmental Science and Pollution Research*, *27*, 25494-25509.

Sodeyfi, S. and S. Katircioglu (2016). "Interactions between business conditions, economic growth and crude oil prices." *Economic Research-Ekonomska Istraživanja*, *29*(1): 980-990.

Tang, C. F. and E. C. Tan (2013). "Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia." *Applied Energy*, *104*: 297-305.

Tang, D., et al. (2023). "Implementation effect of China's green finance pilot policy based on synthetic control method: a green innovation perspective." *Environmental Science and Pollution Research*, *30*(18), 51711-51725.

Ullah, U., Khan, J., Shah, J. A., & Baloch, R. (2023). Customers' experience and perception towards the adaptation of financial services: A special reference to Raast. *UCP Journal of Business Perspectives, 1*(2). http://ojs.ucp.edu.pk/index.php/jbp/index

Ur Rahman, Z., et al. (2019). "An (a) symmetric analysis of the pollution haven hypothesis in the context of Pakistan: a non-linear approach." *Carbon Management*, *10*(3): 227-239.

van der Linde, C. (1995). Green and competitive: ending the stalemate.

Wakelin, K. (2001). "Productivity growth and R&D expenditure in UK manufacturing firms." *Research Policy*, *30*(7), 1079-1090.

Wang, F. and F. Chen (2018). "Board governance, environmental regulation and green technology innovation—Empirical test based on listed companies in China's heavy polluting industry." *Stud. Sci. Sci*, 36(02), 361-369.

Wu, H., et al. (2021). "How does internet development affect energy-saving and emission reduction? Evidence from China." *Energy Economics*, *103*, 105577.

Yin, J., et al. (2018). "Large-scale assessment of global green innovation research trends from 1981 to 2016: A bibliometric study." *Journal of Cleaner Production*, *197*, 827-841.