From Policy to Progress: Evaluating Institutional Quality, Trade Openness, FDI, and Green Technologies' Role in Green Economic Growth Using an ARDL Approach in Emerging Asian Economies

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Abstract

This study scrutinizes the influence of institutional quality, green innovation, foreign direct investment, plus trade openness on green economic growth in emerging Asian countries, with a specific focus on China, India, and Pakistan, covering the period from 1999 to 2023. Using the Autoregressive Distributed Lag (ARDL) model, the research assesses short-run and long-run affiliations among these variables in cooperation. The outcomes illustrate that, in the long run, FDI or green innovation positively contributes to green economic growth, emphasizing their importance in fostering sustainable development. Conversely, institutional quality (IQ) is negatively associated with green growth, suggesting that weak institutional frameworks can hinder environmental progress. TOP also negatively influences green development, likely due to the trade of pollution-intensive goods. In the short run, the effects of FDI are notably adverse. At the same time, the inspiration for green invention, institutional quality, plus trade openness are less significant, implying that their impact on green growth takes more time to manifest. The study finds indications supporting the Environmental Kuznets Curve (EKC) hypothesis for these nations, indicating that conservational degradation initially increases before improving as economic evolution progresses. Partial support is also found for the Pollution Halo Concept, where trade openness and green innovation can lead to cleaner industrial practices over time. Policymakers should focus on improving institutional quality, fostering green FDI, and supporting policies that promote green innovation and sustainable trade practices.

Keywords: Green Growth, Green Innovation, Environmental Kuznets Curve, ARDL.

Introduction

One of the main goals in achieving the sustainable development objectives is the preservation of ecosystems, in particular, good fitness plus well-being (SDG 3), clean water besides sanitation (SDG 6), inexpensive then clean energy (SDG 7), decent work and economic growth (SDG 8),

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maintainable metropolises (SDG 11), accountable depletion as well as fabrication (SDG 12), weather stroke (SDG 13), life below water (SDG 14), besides life on land (SDG 15). These objectives are linked to attaining green economic growth, a theory of economics that contends that environmental protection and economic prosperity are intimately related (Ahmed, Kousar, Pervaiz, & Shabbir, 2022; Degbedji et al., 2024; Osabohien et al., 2023; Yin et al., 2022). However, as nations strive for expansion, it has led to environmental contamination, including carbon emanations, amongst other disputes. Additionally, the pursuit of growth and change has contributed to difficulties such as climate alteration, land degradation, loss of biodiversity, and deforestation (Ahmed, Kousar, Pervaiz, & Shabbir, 2022; Degbedji et al., 2024; Hasnat et al., 2019). However, achieving GG requires establishing a well-functioning institution (Ahmed et al., 2022; Haldar & Sethi, 2021; Karim et al., 2022). The government has started looking for an efficient strategy for sustainable economic progression in light of these conservational disputes. Repeated shortcomings in international policies have underscored the urgency of adopting a new growth paradigm. Consequently, global conversations on achieving sustainable economic growth have gained momentum.

Essential institutional elements that are thought to have a significant influence on ecological tactics and strategies aimed at lowering carbon radiations and ultimately supporting the preference for green economic growth include political stability, corruption, management regulations, the rule of law, or government efficiency (Abid, 2017; Amin et al., 2021; Bhattacharya et al., 2017; Degbedji et al., 2024; Karim et al., 2022). Generally, the quality of institutions is associated with the policies implemented by national institutes to address the official besides traditional circumstances in which socio-economic actions take place (Salman et al., 2019). Thus, by providing the administration's capability to formulate as well as carry out strategies and rules that strengthen the isolated division, improve and diminish enforcement, defend assets' moralities, uphold a strict rule of law, and ensure institutional independence from the political stimulus (Canh et al., 2019; Salman et al., 2019). On the other hand, frail institutions provide insufficient backing to the private sector, leading to corruption, an inefficient civil service structure, and poor environmental policies (Asoni, 2008; Salman et al., 2019).

The green invention helps minimize ecological contamination by enabling access to advanced equipment, which in turn fosters financial development (Wang & Yang, 2021). Building on this perspective, the current study integrates green inventions to explain long-run green financial progression. Green technological innovation presents a latent resolution to environmental contests by supporting sustainable and balanced economic development while improving environmental management (Yang et al., 2020). According to the literature, the GT can help to foster social sustainability, resolve ecological conflicts, and drive economic evolvement by facilitating the evaluation of environmental properties. The study validated a two-way causal bond flanked by imports and urban population and emphasized the beneficial role of trade in reducing ecological deprivation in China. The results showed that the nation's leading causes of environmental deterioration are energy use, urbanization, and imports (Ahmed et al., 2022).

Foreign direct investment is essential in promoting and sustaining green economic development, supporting the evolution to a low-carbon economy, and accomplishing sustainable expansion (Murshed et al., 2021). In terms of environmental sustainability, FDI can encourage a sustainable revolution in addition to supporting green evolution (Amendolagine et al., 2021; Kardos, 2014; Melane-Lavado et al., 2018), due to which welfare costs linked to unsustainable growth and pollution-related deaths are reduced. FDI may, however, have a substantial ecological impact and increase emissions of (i) ozone-depleting gases (like hydro-fluorocarbons and nitrogen oxides),

(ii) acidifying gases (like ammonia and sulfur oxides), and (iii) air contaminants (like ambient PM 2.5 and black carbon), according to some study by, (Doytch, 2020).

Furthermore, FDI can speed up poverty reduction and help decrease income disparity by improving economic complexity, strengthening inter-firm associations both upstream and downstream, enhancing involvement in global value restraints, and promoting long-term evolution and service (Anetor et al., 2020; Opoku et al., 2019; Xu et al., 2021). Chauvin (2020 Wani et al., 2024) note that foreign direct investment entails attaining a long-lasting interest besides monitoring ownership in a business enterprise within a host country. This occurs when an individual or organization from one country undertakes FDI in another. FDI is pivotal in promoting and sustaining green economic evolution, supporting the transition to a low-carbon economy, and achieving sustainable development. The above discussions inspired the investigator to investigate the impact of green invention GI, FDI, IQ or GT on GG of Emerging Asian nations. First, these countries face severe environmental issues, including air pollution, water scarcity, and carbon emissions, which makes green innovation and sustainable growth essential to addressing these challenges.

According to, (Ahmed et al., 2022), the real GDP per capita is measured in purchasing power parity (PPP) at constant $ 2005, enlarged at a compound annual rate of 8.45%. Nevertheless, this growth model is unsustainable as it leads to significant environmental degradation, with a sharp upsurge in carbon emanations being one of the most notable negative impacts. The fast economic evolution in the region leads to a higher mandate for energy, which subsequently increases greenhouse gas (GHG) emissions, mainly carbon. This ongoing rise in carbon emissions contributes to global warming by elevating the Earth's temperature, triggering negative environmental impacts such as climate change and extreme weather patterns.

Third, a significant portion of the population in these Asian economies lives below the poverty line, which means that the region cannot meet the expense of the conciliation of economic improvement in the chase of sustainability. Instead, it inspires financial development within conservational sustainability constraints, promoting ecologically responsible growth. Despite several research studies on achieving green growth, GG has not been identified, nor have the factors that effectively promote GG's green economic growth been found. Nonetheless, this study contributes to the current discussion on green economic growth GG in several ways. To begin with, this research computes the GG for the Asian economies, namely Pakistan, India, and China. This calculation provides insights into how these nations progress towards sustainable economic development while balancing environmental concerns. Second, to the best of the author's acquaintance, this investigation empirically analyses the influences of green technologies and trade on (GG) green economic growth. Thirdly, this research suggests experimental insights into the relationship between green energy, or innovations in GI, trade, and green commercial progression within Asian realms. At a pivotal time when these states are grappling with environmental challenges and striving for sustainable enlargement, the findings not only enrich the remaining literature but also shed light on improving green economic expansion in these provinces. Finally, the study proposes key policy recommendations to accelerate green economic development in emerging Asian economies, aligning them with accomplishing the Sustainable Development Goals (SDGs). These strategies are crucial for fostering sustainable enlargement in these Asian economies. Our study aims to inspect the relationship between green economic evolution, trade openness, and innovation levels in India, Pakistan, and China. We use the auto-regressive distributed lag (ARDL) bounds testing tactic as the statistical technique to identify the empirical connections between these variables. Given the limited research on emerging economies, our

analysis of significant emerging economies like India, Pakistan, and China will serve as a valuable resource for understanding these impacts.

The following segments encompass the rest of this study: Section 2 presents the literature review, Section 3 designates the methodology, Section 4 covers the analysis and findings, and Section 5 determines the consequences of the research.

Literature Review

This section reviews the existing literature, discusses the Environmental Kuznets Curve, and outlines the development of the hypotheses.

Institutional Quality and Green Economic Growth (GG)

Previous studies have explored the effect of institutional quality on a country's ecological conservation and socioeconomic development (Ahmed et al., 2022; Salman et al., 2019; Sarkodie & Adams, 2018). Ahmed et al. (2022) found that institutional quality besides economic development enhance sustainable green financial growth in South Asia over the long term. Similarly, (Osabohien et al., 2023) demonstrate that a green atmosphere has a significant influence on welfare and overall economic growth. Correspondingly (Bhattacharya et al., 2017) originate that institutions play a crucial role in fostering financial progress plus reducing carbon emissions across 85 innovative and evolving economies. The study by (Sarkodie & Adams, 2018) highlighted that in South Africa, both disaggregated plus accumulated factors such as energy, economic expansion, urbanization, besides political institutions play a central role in determining ecological quality. Raju et al. (2020) provided indication showing that in South Asian economies, supremacy besides financial progression are influenced by organizational moralities, managerial stability, then consistency in the rule of law. (Siddiqui & Ahmed, 2019) identified a long-term affiliation in the middle of institutional quality as well as economic growth in Pakistan, with a unidirectional causality consecutively from institutional excellence to economic evolution.

Green Innovation and Green Economic Growth (GG)

Many scientists have explored the impact of technical modernization on both conservation eminence plus economic progress. Numerous studies have concluded that technological invention is essential for improving environmental superiority. In other words, it helps diminish carbon discharges by improving the adeptness of resource exploitation in manufacture (Chan et al., 2016; Haščič et al., 2010; Liu & Liang, 2013; Sohag et al., 2015). Chan et al. (2016) examined the experimental link among technological invention, ecological regulations, plus firm performance via data from Chinese companies. The study found that environmental regulations positively impact innovation, which subsequently enhances firm profitability. (Klewitz & Hansen, 2014) suggested that high-tech innovations are the most effective revenue of attaining efficient, optimal, plus environmentally friendly resource utilization. This not only enhances environmental quality but also improves living standards then fosters social sustainability.

Green Trade and Green Economic Growth (GG)

A multitude of studies has empirically explored the affiliation among trade, financial growth, plus ecological superiority. For example, Yildirim et al. (2012) investigated the impact of trade capacity on cost-effective development also found a positive relationship among trade, economic progress, as well as conservation quality. Trade fosters economic development from side to side various mechanisms, including technology transmission, comparative benefit, then economies of scales.

Similarly, (Alam & Sumon, 2020) found a positive correlation among trade plus economic growth using data from 15 Asian economies. Trade Openness (TO) demonstrate a state's contribution in the worldwide business framework. TO is one way to deal with measure a country's cooperation in the overall exchanging framework. It has been expressed that expanded to brings about various financial advantages, for example, improved innovation moves, work, efficiency, financial development, and supportable turn of events. In contrast, a study (Gulistan et al., 2020) sought to assess the validity of the Environmental Kuznets Curve (EKC) hypothesis by scrutinizing trade openness data from 1995 to 2017. The fallouts maintenance the EKC principle, which suggests that there is no noteworthy statistical association among trade openness and conservational degradation. According to the EKC concept, the affiliation in the middle of ecological contamination plus economic progress trails an inverted U-shaped curve (Akan, 2023). There is an affirmative relationship amid sustainable growth also the impact of stringent conservational strategies on the link between green trade and sustainable expansion (Olasehinde-Williams & Folorunsho, 2023).

FDI and Green Economic Growth (GG)

The impact of foreign direct investment on green economic evolution has been the focus of numerous studies over the past decade. (Ghorbal et al., 2024) conducted a research in South Korea besides discovered that foreign direct investment , gross domestic product , plus domestic patents all play a role in increasing the value of external patents. Therefore, a rise in FDI positively impacts foreign patents, which subsequently fosters greater economic growth and reduces contamination. FDI promotes scientific modernization too enhances national competitiveness amongst local initiatives, leading to lower pollution levels and improved carbon emission efficiency (She & Mabrouk, 2023). On the other hand, the knowledge then advanced equipment brought by FDI to together upstream also downstream productions in an economy generates a multiplier effect that boosts labor efficiency. However, in terms of green economic development, this impact is often uneven across different countries (Wang & Zhang, 2022). Additionally, approximately studies have started to explore the role of intermediary factors in the effect of FDI on the environment. Ofori et al. (2023) explored how energy efficiency mediates the effect of FDI on inclusive green growth in Africa. With a dynamic GMM estimator, the inquiry found that energy efficiency helps lessen the negative impression of FDI on comprehensive green economic evolution. The concept of green growing is closely tied to the Sustainable Development Goals (SDGs), which aim to strike a steadiness amid financial prosperity plus ecological fortification (Caglar et al., 2024; Caglar et al., 2024; Ketchoua et al., 2024).

Theoretical Literature Review

The Environmental Kuznets Curve recommends that economic progression originally leads to environmental degradation, but then after attainment a certain threshold, people starts to recover its environmental practices, and levels of environmental harm begin to decrease. It may also imply that environmental preservation can be an advantage of monetary development. However, opponents argue that there is no certainty that fiscal growth will result in environmental improvements, and this is often not the circumstance. The financial strategies of both developed then unindustrialized countries have been heavily influenced by the EKC hypothesis. According to Webber then Allen, the EKC hypothesis proposes that evolving republics should prioritize swift economic progress slightly than concentrating on pro-environmental measures. They argue that environmental regulations can hinder economic growth, and that over time, economic expansion

will naturally lead to the achievement of both environmental and economic objectives (Webber & Allen, 2010; Zhao et al., 2023). There is no evidence to suggest that all rich realms financing in ecologically friendly besides domestic tools will ultimately achieve environmental progress. Furthermore, there is no proof that affluent societies universally begin prioritizing environmental performance once their basic needs are met (Raymond, 2004; Zhao et al., 2023). Contemporary evolution philosophies also highlight the affirmative role of green equipment in promoting maintainable financial progression (Acemoglu et al., 2016; Ahmed, Kousar, Pervaiz, Trinidad-Segovia, et al., 2022). These theories offer a well-defined conceptual basis for analyzing the connection amongst green invention or sustainable economic development. The "Pollution Halo" concept suggests that foreign direct investment (FDI) can improve vitality and built-up structures by introducing green technology to the host republic also enhancing resource allocation, resulting in reduced carbon dioxide emissions and better environmental quality (Opoku & Boachie, 2020; Wani et al., 2024).

Methodology and Data Collection

Data Sources

The obvious goal of the current investigation is to illuminate the contributions of Institutional Quality, green innovation, trade openness and FDI supports in green growth in the perspective of Emerging Asian States, containing; China India, and Pakistan; three states. For the empirical analysis, the study developed statistics from these certain Asian countries spanning the period from 1999 to 2023. Data were gathered from various sources: green innovation data were sourced from OECD statistics, then data for the remaining components from World Development Indicators. The green economic growth (GG) is measured in ((% of GNI), Foreign direct investment in net inflows (% of GDP), Green Technology in (Environmental-related technologies) and Trade-openness in (Imports of goods and services (% of GDP) or Exports of goods and services (% of GDP).

Table 1 provides a concise description of the variables. To enhance the accuracy of the results, all factors were transformed into their natural logarithmic form.

Table 1: Nomenclature & Explanation

Nomenclature	Explanation
GG	Green Growth
GI	Green Innovation
FDI	Foreign Direct Investment
TOP	Trade Openness
EKC	Environmental Kuznets Curve
PHH	Pollution Halo hypothesis
SDGs	Sustainable development goals
EAN	Emerging Asian Nations (Pakistan, China and India)

Specification of the Model

To discover the connection of how Green innovation plus growth are related, as well as the long-term effects of Institutional Quality, foreign direct investment besides trade openness on Green economic growth have been designed.

The model specification is:

$GG = f(\text{FDI, IQ, GI, TOP})$ 1

After adding the parameters, the equation form is

$$GG = \alpha_0 + \beta_1 FDI + \beta_2 IQ + \beta_3 GI + \beta_4 TOP + \varepsilon_1 \quad 2$$

The Log-linear equation for the study is

$$lnGG_{it} = \alpha_0 + \beta_1(lnFDI_{it}) + \beta_2 (lnIQ_{it}) + \beta_3 (lnGI_{it}) + \beta_4 (lnTOP_{it}) + \varepsilon_{it} \quad 3$$

In eq. (1), GG refers to Green Growth, GI is Green innovation, IQ is institutional quality, FDI is Foreign direct investment, TOP is trade Openness. Since the study is investigating how innovation, FDI, IQ and trade openness on Green Economic Growth, β1, β2, β3, β4, β5 can be affirmative or adverse demonstrating how an upturn or diminution in the troubled variables will effect growth. To analyze the long-term and short-term influences of Green innovation, Institutional Quality, foreign direct investment, plus trade openness on green growth, this research employed the Autoregressive distributed lag (ARDL) model developed by (Pesaran et al., 2001). The ARDL model offers several benefits above outdated co-integration models. Firstly, it allows for testing and estimation of regression terms with both I (0) plus I (1) variables. Likewise, it effectively addresses the issue of en-dogeneity in explanatory variables. Lastly, it can simultaneously estimate the short-term dynamics plus the long-term co-integration connection among elements.

Ahmad et al. (2016) and Yasmeen et al. (2019) contended that the bound testing approach suggested by (Pesaran et al., 2001)is effective when the sample size is large. However, when the sample size is small, this approach may produce biased or misleading results. Erdoğan et al. (2020) shared similar views regarding the use of the ARDL methodology to address this issue.(Narayan, 2005) proposed a method that is effective even with minor sample sizes. Since the sample size in this investigation is small, the technique outlined by (Narayan, 2005)has been adopted.

The equation of an ARDL method as the model with intercept can be written as:

$$\Delta GG_{it} = \alpha_0 + \sum_{i=1}^{m} \beta_{ik} \Delta GG_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta FDI_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta IQ_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta GI_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta TOP_{j,t-i} + \varphi_1 GG_{t-1} + \varphi_2 FDI_{t-1} + \varphi_3 IQ_{t-1} + \varphi_4 GI_{t-1} + \varphi_5 TOP_{t-1} + e_{it} \quad 4$$

I=1,….,N for each nation and t=1,…..,T for each period, βik then it exist nation plus time fixed effects correspondingly, display the predictable residuals.

Table 2: Descriptive of variables

Variables	Description	Measurement unit	Data sources
GG	Green Economic Growth	Adjusted net savings, including particulate emission damage (% of GNI)	WDI
FDI	Foreign Direct Investment	Net inflows (% of GDP)	WDI
IQ	Institution Quality	PCA INDEX (Control of corruption, Government Effectiveness, Political Stability and Absence of Violence/Terrorism, Regulatory Quality, Rule of law, Voice and Accountability)	WDI
GT	Green Technology	"Environmental-related technologies"	OECD
TOP	Trade-openness	(Imports of goods and services (% of GDP) or (Exports of goods and services (% of GDP)	WDI

Results and Discussion

Table 3: Descriptive Statistics

	LOG_GG	LOG_FDI	LOG_IQ	LOG_GI	LOG_TOP
Mean	1.0997	2.1990	0.6379	2.7644	1.5720
Median	1.2244	2.2547	0.6486	2.9631	1.5747
Maximum	1.4323	2.7325	0.9260	5.2545	1.8094
Minimum	0.0603	1.0000	0.0000	1.0000	1.3316
Std. Dev.	0.2885	0.3608	0.1722	1.3325	0.1198
Skewness	-1.1380	-0.7329	-0.9838	0.0774	0.0264
Kurtosis	3.8964	3.5469	4.5742	1.7893	2.0923
Jarque-Bera	18.7015	7.6507	19.845	4.6554	2.5831
Probability	0.0000	0.0218	0.0000	0.0975	0.2748

Table 3 presents measurements for factors used in this inquiry. To ascertain the econometric model, summary statistics for instance mean, standard deviation, maximum and minimum values also demonstrate the dataset's strength. The table displays, the average rate of green monetary development is 1.0997, fluctuating as of 1.4323 to 0.0603. FDI is having a mean value 2.1990 with a minimum value 0.0603 besides the extreme value of 1.4323. The mean rate of green invention is 2.7644 with the smallest 1.0000 then extreme standards of 5.2545, correspondingly. The mean cost of trade openness is 1.5720 ranging from 1.3316 to 1.8094. As well as the average value of IQ is 0.6379 with a 0.0000 and 0.9260 values. Also with a standard deviation of 0.2885. 1.5720, 0.3608, 0.1722, 1.3325 and 0.1198. The Jarque - Bera test is performed to determine whether the residuals are normal.

Empirical Findings

Panel Unit Root

Although not all elements must be stationary in the same order for the ARDL model to work, it is essential to make certain that none of the variables are stationary at the second order before applying the ARDL bound testing approach. This is because the critical values of the F-statistic be contingent on whether the time series are I (0) or I (1). To verify the stationarity of the time series, the research utilized the Augmented Dickey-Fuller then Phillips-Perron unit root tests. The outcome of the unit root test is labeled in Table 3, which revealed an amalgamation of I (0) and I (1) fallouts, while maximum series become stationary after taking first difference.

Table 4: Summary of Unit Root

Variables		ADF	PP	Level of Integration
GG	At level	8.25208	10.7263	I(1)
	Significance	0.2202	0.0972	
	At 1st difference	16.4145	38.5185	
	Significance	0.0117	0.0000	
FDI	At level	4.20799	5.97387	I(1)
	Significance	0.6486	0.4261	
	At 1st difference	21.6555	38.7932	
	Significance	0.0014	0.0000	
IQ	At level	8.45236	10.9581	

	Significance	0.2068	0.0897	I(1)
	At 1st difference	45.3359	49.2103	
	Significance	0.0000	0.0000	
GI	At level	11.7502	26.8653	
	Significance	0.0678	0.0002	I(0)
	At 1st difference	33.3995	90.9236	
	Significances	0.0000	0.0000	
TOP	At level	3.32161	6.80280	
	Significance	0.7675	0.3395	I(1)
	At 1st difference	18.0164	45.940	
	Significance	0.0062	0.0000	

The unit root test consequences from equally the ADF or PP tests confirm that variables such as Ln GG, Ln FDI, Ln IQ, Ln GI, and Ln TOP are stationary at whichever at level I (0) or at 1st difference I (1). This satisfies the ARDL model's prerequisite that variables must be stationary at I (0), I (1), or a combination of both. While the ARDL model can be used to examine the short plus long-term relationships between components, time series statistics might include structural breaks. Thus, it is necessary to conduct a structural breaks unit root test alongside the standard unit root tests. To identify structural breaks within the figures, the study applied the (Kim & Perron, 2009) structural breaks unit root test. The outcomes of this test are presented in table 3.

Application of ARDL Model

Long-run Results of Panel ARDL

However, ARDL Pesaran and Shin (1995) has been more used recently, because of a few useful benefits that are implanted in it. One of the main compensations of this procedure is that it may be applied regardless of whether series are I(0) or I(1) or slightly co-integrated (Adom et al., 2012; Wolde-Rufael, 2010). Another benefit is that mutually short-term plus long-term assessments can be made instantaneously.

Table 5: Results of Long – run Panel ARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
	Long-run (Pooled) Coefficients			
LOG_FDI	-0.646099	0.175352	-3.684588	0.0005
LOG_IQ	1.414881	0.254508	5.559282	0.0000
LOG_GI	0.023638	0.017534	1.348089	0.1829
LOG_TOP	4.289652	0.516151	8.310840	0.0000
C	-5.234974	0.652048	-8.028509	0.0000
	Short-run (Mean-Group) Coefficients			
COINTEQ	-0.282358	0.218345	-1.293173	0.2024
D(LOG_FDI)	-0.172773	0.235919	-0.732341	0.4677
D(LOG_FDI(-1))	0.424016	0.434364	0.976177	0.3341
D(LOG_FDI(-2))	-0.223417	0.219153	-1.019458	0.3133
D(LOG_FDI(-3))	0.090522	0.170367	0.531334	0.5977
D(LOG_IQ)	0.462956	0.655137	0.706655	0.4833
D(LOG_IQ(-1))	-0.293592	0.352234	-0.833514	0.4089
D(LOG_IQ(-2))	-0.247454	0.218994	-1.129961	0.2644
D(LOG_IQ(-3))	-0.809294	0.917236	-0.882319	0.3822

D(LOG_GI)	-0.350083	0.308338	-1.135388	0.2621
D(LOG_GI(-1))	0.606209	0.619278	0.978897	0.3328
D(LOG_GI(-2))	0.529438	0.543165	0.974726	0.3348
D(LOG_GI(-3))	-0.479482	0.468249	-1.023988	0.3112
D(LOG_TOP)	-0.298255	0.445497	-0.669488	0.5065
D(LOG_TOP(-1))	0.325008	0.497572	0.653188	0.5169
D(LOG_TOP(-2))	0.272736	0.083739	3.256976	0.0021
D(LOG_TOP(-3))	0.442065	0.334592	1.321207	0.1930

Note: ***, ** also * specify the significant at 1%, 5%, and 10%, level, correspondingly

We used the panel ARDL-PMG approach to scrutinize the aspects that affect the CO_2 releases. The results of panel ARDL-PMG are shown in table 5. The coefficient of ECT is statistically significant then negative.

Regarding in the long run connotation amongst FDI and GG is negative and significant (-0.65) (Phung et al., 2023). A 1% rise in FDI reduces green growth in the long run, potentially due to environmentally harmful investments. On the other hand, the link between IQ and GG is Positive plus highly significant (1.41) (Wang et al., 2023). Strong institutional quality boosts green growth significantly. As like GG and GI are Positive but not statistically significant (0.02), indicating limited long-term effect on green monetary growth (Chen et al., 2022). But the relation amongst GG and TOP is Strongly positive and significant (4.29) (Song et al., 2019). Increased trade openness supports green growth. Its C value is Negative and significant (-5.23), suggesting systemic factors opposing green growth. In Long Run, Institutional quality and trade openness are key drivers of green economic growth, while FDI has a negative influence, and green innovation shows limited impact. The negative and significant coefficient (-1.3035, $p < 0.01$) indicates that enlarged trade openness could lead to ecological challenges. In the perspective of the Environmental Kuznets Curve (EKC) Dinda (2004) Hypothesis, this could imply that trade-driven growth might initially exacerbate pollution before the benefits of environmental improvements manifest at higher income levels.

In short run results the error correction term is negative but insignificant (-0.28), suggesting slow or weak adjustment to long-run equilibrium. FDI results is Mixed and mostly insignificant impacts in the short run, with varying signs across lagged terms. Institutional quality shows Short-term impacts are inconsistent and insignificant, implying delayed or muted effects. Same like that green innovation is similar to institutional quality, short-term impacts are mixed and insignificant. Trade Openness shows lagged variable D (LOG_TOP (-2)) is significantly positive (0.27), indicating a delayed positive influence of TOP on green financial development in the short term. The significant negative coefficient (-0.3554**,** $p < 0.01$**)** confirms the long-run steadiness connection then indicates that any short-run deviation from equilibrium adjusts back by approximately 35.5% per period. In short run, the adjustment to long-run equilibrium is slow, and short-term dynamics lack strong significance, except for delayed positive effects of trade openness.

In this research, error correction demonstrations with the succeeding stipulations are used to scrutinize the result of long plus short-run dynamics:

$$\Delta \mathrm{GG}_{\mathrm{it}} = \alpha_0 + \alpha_1 t + \sum_{i=1}^{m} \beta_{ik} \Delta GG_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta FDI_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta IQ_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta GI_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta TOP_{j,t-i} + e_{it} \quad 5$$

If there is a co-integration, the preceding phase of ARDL procedure maintains the long-run ARDL equation as follows:

$$\Delta GG_{it} = \beta_0 + \sum_{i=0}^{p} \beta_{ik} GG_{t-i} + \sum_{i=1}^{q} \beta_{ik} FDI_{t-i} + \sum_{i=1}^{r} \beta_{ik} IQ_{t-i} + \sum_{i=0}^{s} \beta_{ik} GI_{t-i} + \sum_{i=0}^{t} \beta_{ik} TOP_{t-i} + e_t \quad 6$$

To select the lag values p, q, r and s in eq. (4), model assortment norms such as AIC, SIC, Hannan–Quinn information criteria, Adjusted R-squared are used. The best estimated model is that wherein the base data measures or the extreme R-squared value. Lastly, the equation below predicts the short-run valuation of ARDL model also recognized as the error-correction model.

$$GG_{it} = \delta_0 + \sum_{i=0}^{p} \delta_{ik} \Delta GG_{t-i} + \sum_{i=1}^{q} \delta_{ik} \Delta FDI_{t-i} + \sum_{i=0}^{r} \delta_{ik} \Delta IQ_{t-i} + \sum_{i=0}^{s} \delta_{ik} \Delta GI_{t-i} + \sum_{i=0}^{t} \delta_{ik} \Delta TOP_{t-i} + e_{it} \quad 7$$

If there happens a shock in short-run, the estimation of ECM (α) helps in determining the rate of alteration toward the equilibrium circumstances throughout the Long-Run.

Correlation Matrix

The table above represents the correlation matrix for five variables: LOG_GG (Green Growth), LOG_FDI (foreign direct investment), LOG_IQ (institutional quality), LOG_GI (green innovation), and LOG_TOP (trade openness). The key interpretations include: (i) LOG_GG has a strong positive correlation with LOG_GI (0.778) plus LOG_TOP (0.706), indicating a significant affiliation among green growth, green innovation, and trade openness. (ii) LOG_FDI shows moderate positive associations with LOG_GG (0.474) and LOG_TOP (0.684), suggesting FDI is moderately linked to green growth and trade openness. (iii) LOG_IQ exhibits weak or negligible correlations with maximum variables, with the strongest being a slight positive correlation with LOG_GI (0.232).

Table 6: Correlation

	LOG_GG	LOG_FDI	LOG_IQ	LOG_GI	LOG_TOP
LOG_GG	1.000000				
LOG_FDI	0.474197	1.000000			
LOG_IQ	-0.136424	-0.085558	1.000000		
LOG_GI	0.778378	0.437918	0.231901	1.000000	
LOG_TOP	0.705727	0.683521	0.023676	0.653227	1.000000

The strong correlation between LOG_GI and LOG_TOP (0.653) highlights a potential linkage between green innovation and trade openness. These results suggest interdependencies between green growth and factors such as trade openness, FDI, and green innovation, with institutional quality having a weaker influence (Weimin et al., 2022).

Conclusion and Recommendations

Achieving sustainable development requires prioritizing Green economic growth. While latest experimental studies suggest that institutional quality influences economic growth, limited research has explored its specific part in promoting green economic development. This investigation adopts this perspective to scrutinize the stimulus of institutional quality, foreign direct investment, trade, besides innovation on green economic growth in emerging Asian countries from 1999 to 2023. This study represents an experimental effort to scrutinize the factors influencing green growth in emerging countries (Pakistan, India and China) within the frameworks of the PHH and EKC hypotheses. To achieve this, we employ the panel ARDL-PMG approach. Our outcomes sanction the rationality of both the PHH and EKC hypotheses for these nations.

Using panel-ARDL method in these Emerging nations the finding affirms that in long-run FDI and GG has negative and significant results on the other side Institutional quality and GG has favorable and highly imperative results. In the same way, the trade openness and Green growth shows Strongly positive and significant outcomes. In additionally, Green innovation and GG shows a Positive but not statistically significant association among them. Foreign direct investment has a negative consequence on green economic enlargement, suggesting that foreign investments may not prioritize environmental sustainability. The Error correction term highlights the moderate swiftness at which the organization yields to equilibrium, suggesting that structural reforms and adjustments take time to yield desired outcomes. Institutional Quality (IQ) has strongly boosts green financial evolution, highlighting the importance of real authority and policies. The Green Innovation (GI) has minimal long-term effect, indicating that technological advancements may not yet be fully integrated into sustainable growth strategies. The Trade Openness (TOP) has highly positive impact, showing that open trade policies encourage green growth through cleaner production and technologies. Negative coefficients in the short run suggest that initial inflows of FDI may subsidize to higher emanations, potentially due to the pollution haven hypothesis, where less stringent environmental regulations attract polluting industries.

The results of the study provide several important perceptions into the aspects manipulating green financial growth in emerging Asian nations. The findings demonstrate that institutional quality shows a substantial positive part in stimulating green progress in the long run. This highlights the importance of well-functioning institutions, which provide a stable environment for sustainable policies and regulations. Countries open to trade are more likely to adopt global sustainability standards, benefiting from cleaner production techniques and innovation through collaboration. The relatively weaker impact of green innovation on economic growth designates that technological advancements in these countries are not yet fully leveraged for sustainability.

These findings emphasize that while emerging economies have made strides in integrating global markets and attracting investment, structural challenges and strategy holes prevent the change to a green economy. Policymakers in Pakistan, India, and China must take a comprehensive strategy that incorporates economic, environmental, and governance strategies to ensure sustainable development. By addressing institutional weaknesses, fostering innovation, and aligning trade and FDI policies with environmental goals, these nations can achieve a balanced trajectory of economic growth and environmental preservation. Future efforts must also focus on international collaboration, energy transition, and raising public awareness to create a green economy that is resilient and sustainable.

The study’s limitations present several avenues for future research. First, the findings are region-specific, limiting generalizability across other developing or developed regions and sectors. The use of composite indicators for institutional quality and green innovation, along with the lack of differentiation between green and conventional FDI, further limits the study's precision. Additionally, the short time frame (1999–2023) and unaddressed structural breaks may obscure long-term trends besides the effects of external shocks. The exclusion of variables such as cultural factors, environmental degradation, and specific climate change policies presents another limitation, as does the reliance on linear modeling that may not capture non-linear relationships or dynamic spillovers. Furthermore, addressing potential endogeneity issues and expanding data coverage would improve the robustness of the results.

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