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IZA DP No. 17900

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MAY 2025

I Z A Institute
of Labor Economics

Initiated by Deutsche Post Foundation

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ISSN: 2365-9793

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ABSTRACT

The Green Path: FDI's Influence on Asia's Sustainable Economic Growth

This study examines the dual impact of Foreign Direct Investment (FDI) on sustainable economic growth in Asia, focusing on its effects on Green GDP, greenhouse gas (GHG) emissions, and the Environmental Performance Index (EPI). Using data from 38 Asian countries spanning 1999 to 2022 and employing a two-step GMM regression analysis, the findings reveal that while FDI positively influences Green GDP growth, it concurrently exacerbates GHG emissions and reduces EPI scores. These results underscore the paradoxical role of FDI in fostering economic growth while posing environmental challenges. The study highlights the importance of robust environmental policies, investment in green technologies, and regional cooperation to align FDI with sustainability goals. It also emphasizes the need for a balanced approach to leverage FDI's economic benefits without compromising environmental integrity. This research contributes to the literature by providing a comprehensive analysis of FDI's environmental and economic implications in the Asian context, offering policy recommendations for achieving sustainable development.

JEL Classification: F20, F21, O11, O44, O53, Q56

Keywords: foreign direct investment, green economy, sustainable economic growth, Asia

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1. Introduction

The urgency of transitioning to sustainable development models is increasingly evident as the world faces severe consequences from climate change and environmental degradation. The rapid increase in natural disasters, environmental refugees, and adverse impacts on human health underscores the pressing need to balance economic growth with environmental protection. In response, the concept of inclusive green growth has emerged as a core strategy for sustainable development, emphasizing the integration of economic, social, and environmental objectives (World Bank, 2012; Sun et al., 2020; Maiti, 2022; Ofori et al., 2023).

While governments worldwide acknowledge the importance of green growth, many still depend heavily on Foreign Direct Investment (FDI) to fuel economic expansion. This reliance raises a critical question: can FDI be harnessed to support both economic prosperity and environmental sustainability? Although extensive literature documents the economic benefits of FDI—such as increased capital, technology transfer, and managerial skills—the interaction between FDI inflows and green development, particularly in Asia, remains underexplored. Asia not only accounts for a significant portion of global FDI inflows but also faces unique challenges ranging from rapid industrialization to weak environmental regulations in some countries. Understanding this duality is crucial for policymakers aiming to align FDI strategies with sustainable development goals.

In today's globalized world, attracting FDI is critical for national development. To meet the United Nations' Sustainable Development Goals (SDGs), especially those related to decent work, innovation, and climate action, Asian governments must ensure that the influx of FDI aligns with environmental objectives. Empirical studies have demonstrated that FDI contributes to long-term economic growth by enhancing productivity and creating sustainable wealth through capital inflows, employment generation, and poverty reduction (Pegkas, 2015; Opoku et al., 2019; Ofori and Asongu, 2021). However, the environmental impact of FDI is contentious.

On one side, the Pollution Halo Hypothesis argues that FDI can improve environmental sustainability by facilitating access to advanced, eco-friendly technologies, thereby boosting renewable energy consumption and supporting economic growth. For example, Apergis and Payne (2010) found that renewable energy consumption positively correlates with economic growth in OECD countries. On the other side, the Pollution Haven Hypothesis suggests that FDI may lead to environmental degradation when multinational corporations invest in pollution-intensive industries in countries with lax regulations, thus increasing carbon emissions (Cole and Elliott, 2005). The overall effect of FDI on environmental quality, therefore, depends on the host country's policy framework and enforcement mechanisms.

Recent data indicate that FDI into developing Asia remained steady at $662 billion in 2022, accounting for about half of global investment flows. In ASEAN countries, FDI increased significantly, with greenfield projects and investments linked to the SDGs rising markedly. Motivated by the need to clarify FDI's role in green economic development in Asia, this study addresses key gaps in the literature by examining both economic and environmental impacts simultaneously. Unlike previous research that predominantly relies on traditional

GDP metrics, this study incorporates Greenhouse gas emissions, Green GDP, and the Environmental Performance Index (EPI) as dependent variables. Green GDP adjusts for environmental degradation and resource depletion, while the EPI offers a broad evaluation of environmental quality. To achieve this, the study employs stepwise regression with a two-step GMM analysis using panel data from 38 Asian countries spanning 1999 to 2022. The findings reveal that while FDI positively contributes to Green GDP growth, it also leads to increased greenhouse gas emissions and a decline in EPI scores. These dual effects highlight FDI's complex role as both an engine of economic expansion and a potential driver of environmental degradation.

The rest of the paper is structured as follows: Section 2 reviews the literature; Section 3 presents the data and methodology; Section 4 discusses the findings; and Section 5 concludes with a summary and policy recommendations.

2. Literature Review

2.1. Green growth and its measurements

Green growth is a sustainable economic model aiming to efficiently utilize resources while minimizing negative environmental impacts. OECD (2022) emphasizes that economic development and environmental protection should be mutually supportive, enhancing life quality and ecosystem preservation. Originating from the 2005 Seoul Initiative in the Asia-Pacific region, green growth has become a strategy for achieving the MDGs, particularly poverty reduction and environmental sustainability (UNESCAP, 2012). Post-2008 financial crisis, countries increasingly adopted green growth for economic recovery; South Korea notably became a global leader through its strategic implementation of low-emission development policies (UNESCAP, 2012).

The World Bank (2012) highlights that transitioning to green growth reduces carbon emissions, creates employment opportunities, and promotes innovation, urging governments to invest in renewable energy and sustainable infrastructure. International organizations like the GGGI and GGKP further support this global transition by facilitating knowledge exchange (Atkisson, 2012). To measure green growth, various indicators are utilized extensively in the literature. Green Growth Index (GGI) assesses progress in sustainable development, incorporating renewable energy, energy efficiency, and environmental preservation. Phung et al. (2022) found higher GGI scores attract greater FDI inflows in Asia-Pacific. Similarly, Ofori et al. (2023) demonstrated the synergy between energy efficiency and FDI in promoting inclusive green growth in Africa. Environmental Sustainability Index (ESI) evaluates ecosystem health and resource sustainability. Esty and Porter (2005) noted improved environmental outcomes when FDI is accompanied by robust environmental policies in OECD countries. Green GDP adjusts traditional GDP by considering environmental costs, providing a clearer measure of sustainability. Hamilton and Clemens (1999) found that countries adopting Green GDP typically pursued stronger sustainability policies. The World Bank (2012) similarly used Green GDP to assess sustainable growth strategies linked to FDI, underscoring its policy importance. Heshmati (2018) provides a comprehensive review of the green economy through this indicator.

Greenhouse Gas Emission Index measures greenhouse gases related to climate change, crucial for assessing sustainability. Research consistently links emission reductions to successful green growth. Environmental Performance Index (EPI) evaluates effectiveness in achieving environmental goals such as air quality, water management, and ecosystem preservation. Tsoy and Heshmati (2024) applied EPI to demonstrate how FDI may impact environmental performance adversely. These indicators collectively demonstrate that FDI significantly influences sustainable development outcomes, highlighting the importance of policy alignment in achieving green growth goals.

2.2. Brief of the literature

2.2.1. Relationship between FDI and economic growth

FDI significantly influences global economic development, fostering international trade, technology transfer, and job creation. Alfaro (2017) notes that open-door policies have enabled developing nations to participate in global supply chains, boosting economic progress, improving labor skills, and enhancing national incomes. For host countries, FDI accelerates technological advancements, increases productivity, and offers higher wages compared to domestic firms, thereby reducing unemployment and poverty (Opoku et al., 2019; Ofori & Asongu, 2021). Investing countries benefit through expanded global markets, optimized profitability, and strengthened financial stability (Lipsey and Sjoholm, 2004).

Since the 1980s, Asian nations like China, India, and Vietnam have greatly benefited from liberalizing FDI policies, attracting significant foreign capital. This inflow has spurred job creation, infrastructure development, and technological upgrades, positioning these countries higher in global value chains (Kokko et al., 2022). Empirical studies confirm these positive outcomes. Ray (2012) demonstrated that FDI notably contributed to India's GDP growth, particularly in technology-intensive sectors. Zhang et al. (2023) emphasized that FDI not only boosts economic growth but also encourages innovation. Similarly, Kim and Saito (2018) stressed FDI's potential to drive sustainable development. However, Gul (2003) cautioned about potential short-term gains and "FDI traps", emphasizing the necessity for strong regulatory frameworks to ensure sustainable, long-term benefits. Research supports the role of FDI as a critical driver of economic development in Asia, contingent upon effective policies that promote investments aligned with global sustainability goals.

2.2.2. Relationship between FDI and green growth

FDI plays a multifaceted role in advancing green growth and sustainability in developing nations. While globalization has enabled these countries to leverage FDI for economic gains, achieving an equilibrium between such gains and environmental preservation remains challenging (UNCTAD, 2022). The influence of FDI on green growth varies considerably, depending on energy efficiency, regulatory frameworks, and local policy contexts. These factors collectively determine whether foreign capital inflows bolster or undermine environmental outcomes.

Several empirical investigations highlight FDI's dual impact on green growth. Ofori et al. (2023) find that FDI can significantly boost inclusive green growth in Africa when paired with efficient energy use. Similarly, Tsoy and Heshmati (2024) note that, although FDI may heighten pollution in certain settings, strong environmental regulations can mitigate its negative effects. This underscores how regulatory quality shapes FDI's overall role in environmental sustainability. Moreover, the distinction between developed and developing countries also proves crucial. Tawiah et al. (2021) argue that wealthier nations typically manage to capitalize on green infrastructure, favorable tax policies, and renewable energy investments more effectively, while developing countries struggle with limited resources and weaker regulatory enforcement.

Innovation constitutes a further pathway through which FDI can drive sustainable development. Maasoumi et al. (2021) document a rise in patenting activity for renewable energy technologies, signaling FDI's potential to foster technological innovation. Yet, they also caution that limited access to these innovations in many developing regions can curtail such benefits. Research by Phung et al. (2023) on Southeast Asia reinforces this view, demonstrating how strategic FDI directed toward renewable energy and sustainable infrastructure can facilitate economic recovery in the wake of disruptions such as the COVID-19 pandemic. Together, these findings underscore the importance of guiding FDI toward green sectors.

Conversely, a substantial body of literature links FDI to environmental risks, particularly when regulatory frameworks are inadequate. Studies by Zakaria and Bibi (2019) and Khan and Ozturk (2020) show that in Asia, the combination of financial development and FDI frequently escalates pollution levels, underscoring the necessity for robust environmental safeguards. Additionally, Balli et al. (2021) and Ahmed et al. (2022) indicate that FDI-driven industrialization often results in elevated carbon emissions, further highlighting the need to integrate green strategies into FDI inflows.

The broader discourse on FDI's environmental repercussions is shaped by two main theoretical perspectives: the pollution haven hypothesis and the pollution halo hypothesis. According to the pollution haven hypothesis, FDI flows to countries with lax environmental regulations, thereby intensifying pollution and ecological degradation. Numerous studies offer empirical support for this view. For example, Bokpin (2017), Doytch and Uctum (2016), and Shahbaz et al. (2015) show that trade liberalization and FDI inflows can spur carbon dioxide (CO_2) emissions as multinational firms seek lower production costs in regions with weak environmental standards. Consequently, developed countries benefit economically, while poorer nations bear the ecological burden.

Additional evidence for the pollution haven hypothesis arises from region- and sector-specific analyses. Cai et al. (2016) reveal that stringent environmental regulations deter FDI in Chinese cities, prompting firms to invest in areas with lenient standards. Dam and Scholtens (2008) echo this trend, indicating that multinational enterprises relocate polluting operations to countries with weaker controls. In Southeast Asia, Cui et al. (2014) report that industries like chemicals and metals degrade air and water quality in host nations, while Shahzad and Aruga (2023) extend these findings to East Asia, where energy-intensive sectors favor countries with lower environmental protections. Similarly, Mukhopadhyay and

Chakraborty (2006) highlight pollution-intensive FDI in India's manufacturing sector, a phenomenon also observed in South Korea by Chung (2014). Wagner and Timmins (2009) document that Germany's chemical industry, when unconstrained by stringent regulations, exacerbates waste and air pollution. Meanwhile, Kawata and Ouchida (2013) and Cole et al. (2014) propose the notion of "pollution outsourcing," wherein corporations from countries with high pollution mitigation costs shift the most contaminating production stages to locales with more lenient environmental policies.

In contrast, the pollution halo hypothesis suggests that FDI can improve environmental standards in host countries by introducing advanced and cleaner technologies and more sustainable business practices. Güvercin (2019) supports this stance, noting that multinational firms often transfer eco-friendly innovations that reduce pollution and bolster sustainability. This positive effect is particularly evident in renewable energy, where FDI can accelerate the adoption of cleaner power sources and diminish reliance on conventional fossil fuels (UNCTAD, 2010). UNCTAD (2010) further underscores the role of FDI in supporting environmental quality by facilitating investment in renewable energy, waste management, and recycling activities.

Nevertheless, FDI's overall environmental impact is neither universally negative nor unambiguously positive. Bu and Wagner (2016) provide a nuanced perspective, showing that investment decisions can hinge on firm-specific strategies and motivations. Some companies engage in a "race to the bottom" by seeking jurisdictions with minimal regulatory constraints, while others commit to sustainability and opt for markets with stricter environmental standards. Tole and Koop (2011) illustrate this dynamic in mining, where companies with limited environmental commitments favor loosely regulated regions, whereas sustainability-oriented firms choose locations with robust policies, despite higher costs.

Collectively, these studies demonstrate the complexity of FDI's environmental effects. While certain evidence supports the pollution haven hypothesis, suggesting that weak regulations attract polluting industries, other findings indicate that FDI can foster greener outcomes through technology transfer and sustainable practices. As a result, determining whether FDI promotes or undermines environmental sustainability in host countries depends on firm-specific motivations, the strength of regulatory frameworks, and broader policy environments. To maximize FDI's potential for advancing green growth, policymakers must implement regulations that encourage responsible investment and effectively balance economic development with ecological protection.

2.3. Research gaps and contribution of this paper

Although numerous studies have explored the relationship between FDI and economic growth, significant gaps remain concerning its implications for green growth, especially within the diverse socioeconomic and regulatory landscapes of Asia. Existing research often overlooks the dual impacts of FDI on economic development and environmental sustainability simultaneously. Most analyses typically examine either economic growth or environmental outcomes independently, rather than considering their interaction. Moreover, prior studies have mainly addressed global or regional contexts like Africa or Europe, leaving

Asia relatively underexplored. Given Asia's substantial share of global FDI inflows coupled with its unique environmental challenges resulting from rapid industrialization and population growth, an Asia region-specific investigation is essential.

This study addresses these gaps by providing an integrated assessment of FDI's role in sustainable development in Asia, using two critical dependent variables: Green GDP and the EPI. These variables represent a significant methodological advancement over traditional GDP-focused studies, capturing both economic and environmental dimensions of growth. Green GDP, unlike conventional GDP, accounts explicitly for environmental degradation and resource depletion, thus offering a superior and policy-relevant measure of sustainable economic progress. Meanwhile, the EPI incorporates diverse environmental indicators such as air quality, biodiversity conservation, and climate policy effectiveness, enabling a holistic understanding of FDI's broader environmental impacts.

One major contribution of this study is its analysis of the moderating role of environmental policies in influencing FDI's environmental outcomes. While existing literature acknowledges the potential for stringent regulations to guide FDI toward sustainability, few studies comprehensively examine the consequences of weak or absent policies—conditions prevalent in many developing Asian countries. This research explicitly evaluates how differing policy environments shape the environmental impact of FDI, underscoring the necessity for robust governance mechanisms to ensure that foreign investments align with long-term sustainability objectives.

Furthermore, this study tackles the overlooked area of sectoral disparities in FDI's environmental impacts. Past research predominantly assesses FDI at an aggregate level, neglecting nuanced, sector-specific implications. By highlighting sectors such as renewable energy, green technologies, and clean industries, this analysis reveals how targeted sectoral investments can drive sustainable growth. Additionally, it integrates qualitative dimensions like corporate social responsibility (CSR) and public perception, providing a more detailed evaluation of how corporate practices influence environmental outcomes.

A critical limitation of prior research is its reliance on short-term or cross-sectional data, failing to capture the dynamic evolution of FDI's impacts on sustainable development. This study addresses this limitation by utilizing an extensive dataset spanning over two decades (1999–2022) for 38 Asian countries. This longitudinal approach allows for a comprehensive analysis of long-term trends, capturing shifts driven by globalization, policy evolution, and changing priorities around sustainability.

Moreover, this research contributes by integrating globalization-related variables—such as trade openness, financial development, and remittances—that have significant yet underexplored implications for green growth. These factors influence capital flows, facilitate technology transfers, and shape policy adoption, thus playing a crucial mediating role in how FDI affects sustainable development outcomes. By incorporating these variables into the analysis, this research offers nuanced insights into their interdependencies and highlights how globalization can either enhance or mitigate FDI's positive effects on sustainability.

Another notable contribution is the study's examination of key theoretical frameworks—specifically, the Pollution Haven Hypothesis and the Environmental Kuznets Curve—in the

Asian context. Although widely discussed globally, these theories have rarely been contextualized within Asia's diverse regulatory and socioeconomic environment. This analysis revisits and adapts these frameworks, providing valuable insights for regional policymakers on how to design effective regulations and strategies that balance economic development with environmental protection.

In conclusion, this study significantly advances the existing literature on FDI and green growth, particularly within Asia. By explicitly adopting Green GDP and the EPI as core dependent variables, it shifts beyond traditional economic assessments, delivering a richer and more relevant evaluation of FDI's environmental implications. The extensive longitudinal dataset allows for capturing nuanced and long-term dynamics of FDI impacts. Moreover, emphasizing the moderating role of environmental regulations, sector-specific analyses, and globalization-related factors provides practical insights crucial for effective policymaking. Revisiting major theoretical frameworks in the unique Asian context also enhances theoretical clarity and relevance. Collectively, this research offers policymakers and investors actionable guidance, underscoring the importance of strategically aligning foreign investments with sustainable development goals, thereby promoting balanced and enduring green growth throughout Asia.

3. Data and Methodology

3.1. Data and variables

The study utilizes balanced panel data from 38 Asian countries covering the period from 1999 to 2022, sourced from the World Bank and IMF. Due to limited data availability, it was not feasible to collect data for all Asian countries. Nations severely impacted by war, were omitted from the dataset. In addition, some missing values are estimated using the Interpolation method (Shao et al., 2014) to solve the unbalance of the panel data.

We employ three dependent variables: Greenhouse Gas Emissions (GHG), Green GDP, and the Environmental Performance Index (EPI). The descriptions and sources of dataset is presented in Table 1.

Table 1: List of the variables, their definitions, and sources.

ACRONYM	UNIT	DEFINITION	SOURCE
A. DEPENDENCT VARIABLES			
GHG	kt of CO2 equivalent	Total greenhouse gas emissions	WB
EPI	Index	Environmental Performance Index	Wolf et al. (2022), Yale University
GREENGDP	constant 2015, billion US dollar	Estimated and calculated based on Stjepanovic et al. (2022)	Stjepanovic et al. (2022)
B. *INDEPENDENT VARIABLES*			

GDPP	constant 2015 US dollar	GDP per capita (GDP/midyear population)	WB
FDI	constant 2015 US dollar	Foreign direct investment refers to direct investment equity inflows in the host economy	IMF
TRADE	% of GDP	Trade is the sum of exports and imports of goods and services measured as a share of GDP.	WB
VULEM	% of total employment	Vulnerable employment is contributing family workers and own-account workers as a percentage of total employment.	WB
IND	% of GDP	The industry sector (including construction, ISIC divisions 05-43) and manufacturing (ISIC divisions 10-33). It is measured as net value added by industry as a percentage of aggregate GDP	WB
REMIT	constant 2015 US dollar	Personal remittances include transfers between resident and non-resident households and earnings of short-term workers in economies other than their residence	WB
RENW	% of total final energy consumption	Renewable energy consumption is the share of renewable energy in total final energy consumption.	WB
INV	constant 2015 US dollar	Investment is accumulated capital assets, such as machinery, infrastructure, and technology, which enhance an economy's productive capacity over time.	WB
FIN	Index	Financial Development Index	IMF

Logarithmic transformation is applied to some continuous variables to facilitate data processing and analysis. Summary statistics of the data providing a more comprehensive picture of the data structure is presented in Table 2. Correlation matrix reported in Table 3 show the relationships between the variables.

Table 2. Summary Description of variables in the empirical model

VARIABLE	OBS	MEAN	STD. DEV.	MIN	MAX
ASIAN COUNTRIES					
LOG_GHG	912	11.488	1.802	6.848	16.416
LOG_GREENGDP	912	4.158	2.064	-0.909	9.772
EPI	912	52.589	24.789	0	100.000

LOG_GDPP	912	8.313	1.510	4.921	11.493
FDI	912	1.06E+10	3.30E+10	-2.60E+10	3.44E+11
LOG_FDI	870	21.197	2.210	13.811	26.564
TRADE	912	88.232	58.871	0.175	437.327
VULEM	912	38.337	25.874	0.138	87.150
IND	912	34.926	16.032	5.103	128.677
REMIT	912	4.44E+09	1.08E+10	0	1.11E+11
LOG_REMIT	812	20.665	2.263	12.960	25.435
LOG_INV	912	23.492	2.354	15.805	29.674
FIN	912	0.348	0.194	0.030	0.930
RENW	912	23.419	26.835	0	92.000

Table 2 shows that there are differences in the number of observations between pairs of FDI and log_FDI, as well as remit (remittance) and log_remit. For FDI inflows, some negative values prevent the calculation of the log for these values. There are several reasons for negative FDI inflows in countries, such as in 2022, when Brunei's FDI inflows were -292,416,275 USD due to a decrease in equity and debt instruments, resulting in negative FDI inflows (Brunei Darussalam, 2022). Additionally, capital withdrawal from dividend payments in the extractive industries contributed to negative FDI inflows to Azerbaijan, with values of -1.7 and -4.4 billion in 2021 and 2022, respectively (UNTACD, 2023). Other factors also led to negative FDI inflows. According to data from the World Bank, no remittance were received in Brunei, Singapore, the United Arab Emirates, and several other countries during the period from 1999 to 2004. The zero values are replaced by 1 which in log form become zero.

Table 3. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) log_ghg	1.000											
(2) log_greengdp	0.889	1.000										
	(0.000)											
(3) EPI	-0.852	-0.801	1.000									
	(0.000)	(0.000)										
(4) log_GDPP	0.159	0.449	-0.242	1.000								
	(0.000)	(0.000)	(0.000)									
(5) log_FDI	0.680	0.790	-0.571	0.466	1.000							
	(0.000)	(0.000)	(0.000)	(0.000)								
(6) trade	-0.259	-0.144	0.233	0.309	0.169	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)							
(7) vulem	-0.084	-0.259	0.135	-0.805	-0.267	-0.297	1.000					
	(0.011)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
(8) ind	0.135	0.110	-0.214	0.443	0.083	0.094	-0.414	1.000				
	(0.000)	(0.001)	(0.000)	(0.000)	(0.015)	(0.005)	(0.000)					
(9) log_remit	0.519	0.560	-0.486	-0.049	0.518	-0.235	0.101	-0.169	1.000			
	(0.000)	(0.000)	(0.000)	(0.167)	(0.000)	(0.000)	(0.004)	(0.000)				
(10) log_inv	0.784	0.892	-0.696	0.477	0.708	-0.051	-0.285	0.168	0.505	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.125)	(0.000)	(0.000)	(0.000)			
(11) fin	0.472	0.691	-0.448	0.706	0.640	0.328	-0.552	0.150	0.225	0.676	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(12) renw	-0.315	-0.348	0.275	-0.688	-0.440	-0.238	0.731	-0.389	-0.065	-0.436	-0.526	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.063)	(0.000)	(0.000)	

The results presented in Table 3 show the correlation coefficients between the main variables, providing insights into the relationship between green growth and various factors within the context of sustainable development. Notably, the GHG emissions variable (log_ghg) exhibits a strong positive correlation with Green GDP (log_greengdp) (0.8895), indicating a close relationship between environmental indicators and green economic development. However, log_ghg is negatively correlated with the EPI (-0.0844), which may reflect the fact that higher emissions do not necessarily lead to better environmental performance.

FDI shows a significant positive correlation with log_greengdp (0.790) and log_ghg (0.680), suggesting that foreign investment may contribute to growth but also come with environmental costs, possibly because investment activities support rapidly growing industries that also lead to increased emissions. Additionally, FDI is positively correlated with log_GDPP (0.446), emphasizing the role of foreign investment in increasing per capita income.

Furthermore, the vulnerability of the labor force (vulem) shows a negative correlation with Green GDP (-0.2591) and log_ghg (-0.0841), which may indicate that economies with higher proportions of vulnerable employment tend to be less sustainable. When considering sustainability factors, it is observed that Renw (renewable energy) has a negative correlation with FDI (-0.4403), suggesting that economies heavily reliant on renewable energy may be less attractive to foreign investment. Moreover, EPI is slightly negatively correlated with FDI (-0.571), reflecting that countries with higher foreign investment inflows tend to achieve lower environmental performance. This could signal a conflict between the economic activities brought by FDI and environmental sustainability goals.

In conclusion, the pairwise correlation coefficients highlight the complex relationships between sustainable development factors, trade, investment, and environmental performance, underscoring the need for further econometric investigation to clarify their causal relationships in the context of green growth.

3.1.1. Dependent variables

To measure green growth in Asia, we use three measures: greenhouse gas emissions (GHG), Green Gross Domestic Product (Green GDP), and the Environmental Performance Index (EPI).

Greenhouse gas emissions (GHG)

GHG emissions are among the most widely used indicators to measure environmental impact and green growth, as they directly reflect the emissions of carbon dioxide (CO_2) and other greenhouse gases. Reducing GHG emissions is a critical objective for countries transitioning toward a green economy, as it helps to mitigate climate change and its adverse effects on human health and ecosystems (Pachauri et al., 2014).

Ofori et al. (2023) and De Pascale et al. (2020) have selected greenhouse gas emissions as an indicator in their studies on the relationship between FDI and sustainable green growth, asserting that environmental sustainability extends beyond CO_2 emissions by including other pollutants. Stern (2008) also emphasized that controlling GHG emissions is crucial for sustainable development, as CO_2 emissions are closely tied to industrialization and energy consumption. In this study, GHG is measured by CO_2 emissions in million tons, based on World Bank data, to indicate the level of environmental pollution in various countries.

Green Gross Domestic Product (Green GDP)

Green GDP is an improved concept of traditional GDP, designed to assess sustainable economic growth by subtracting the costs and damages resulting from environmental degradation and the depletion of natural resources. Vaghefi et al. (2015) argued that traditional GDP fails to adequately reflect the costs of pollution and resource depletion, leading to a flawed assessment of economic development. By excluding these costs, Green GDP provides a more comprehensive view of net economic growth and environmental sustainability (Bhaskar et al., 2023).

In this study, Green GDP is used as a dependent variable and is calculated based on the formula and dataset provided by Stjepanović et al. (2022). However, in the latest study by this group of authors, Green GDP calculations only extend to the year 2019. To meet the objectives and time scope of this research, we computed the missing values ourselves using Stjepanović et al.'s (2022) developed formula, with the necessary data sourced from the World Development Indicators (WDI) by the World Bank. The formula for calculating Green GDP is as follows:

$$Green\ GDP = GDP - (KtCO_2 * PCDM) - \\ -(Twaste * 74kWh * Pelect) - (\frac{GNI}{100} * \%NRD)$$

(1)

where Green GDP represents GDP adjusted to reflect environmental sustainability, expressed in current U.S. dollars. GDP is the total gross value added by all resident producers in an economy, including taxes and excluding subsidies, without considering depreciation of manufactured assets and depletion of natural resources. CO_2 emissions (in kilotons) include all CO_2 emissions from burning solid, liquid, and gaseous fuels, as well as gas flaring. PCDM denotes the weighted average carbon price in purchasing power parity (PPP). Waste is the total commercial and industrial waste in tons, where its value is converted into energy (1 ton of waste = 74 kWh). Pelect is the average price of electricity in PPP per kilowatt-hour. GNI (Gross National Income) is the total value added by domestic producers, including taxes, less subsidies, and net income from abroad. Natural Resource Depletion (NRD) is the percentage of GNI that reflects the depletion of mineral, energy, and forest resources.

Environment Performance Index (EPI)

Regarding the third measure of environmental sustainability, we use the Environmental Performance Index (EPI) to estimate the impact of FDI inflows on environmental sustainability. According to Wolf et al. (2022), the EPI is a composite index uses 58 performance indicators across 11 issue categories, including factors such as air quality, water, biodiversity, and pollution reduction efforts. The EPI is designed to assess and rank performance in climate change, environmental health, and ecosystem vitality, allowing for comparisons of environmental protection and sustainability across different countries. In their annual EPI report, Wolf et al. (2022) also provide practical recommendations for countries aiming toward a sustainable future.

The study by Esty et al. (2008) demonstrates that the Environmental Performance Index (EPI) is an effective tool for assessing environmental sustainability and developing targeted improvement strategies based on specific environmental factors. In this study, the EPI is used as a dependent variable to evaluate the environmental protection performance of Asian countries, where higher scores indicate better green growth. The authors also note that the EPI focuses on two primary environmental objectives: "reducing environmental stress on human health" and "promoting ecosystem vitality and sound natural resource management." This index is measured on a scale from 0 to 100, with higher values closer to 100 indicating greater environmental sustainability. Tsoy and Heshmati (2024) also utilized the EPI in their study to measure the impact of FDI inflows on the environment in over 100 countries worldwide.

3.1.2. Independent Variables

The primary independent variable examined in this study is FDI, defined as the net inflow of foreign direct investment capital measured in U.S. dollars. FDI's environmental impact is often debated through two theoretical frameworks: the pollution halo hypothesis, suggesting that FDI promotes environmental sustainability by transferring cleaner technologies, and the pollution haven hypothesis, proposing that FDI might undermine environmental quality due to weaker regulatory standards in host countries (Sarkodie et al., 2020; Golub et al., 2011). Despite these competing views, this research anticipates a positive relationship between FDI and environmental sustainability indicators, aligning with the objectives of the United Nations' SDGs.

Alongside FDI, several macroeconomic determinants with direct and indirect impacts on environmental sustainability are considered. The first is GDP per capita, capturing how economic growth influences green development. Increased economic activity typically escalates resource consumption and production intensity, placing more pressure on ecosystems and increasing greenhouse gas emissions (Tawiah et al., 2021). However, according to the Environmental Kuznets Curve (EKC) hypothesis, this negative environmental impact may decrease once countries achieve higher income levels and begin investing in sustainable technologies and cleaner energy sources, thus transitioning towards green growth (Kaika et al., 2013).

Another critical macroeconomic variable included is vulnerable employment (vulem), reflecting labor market stability. This is especially relevant for Asian countries, characterized by high rates of informal employment, self-employment, and unpaid family labor, influencing the feasibility and effectiveness of green initiatives. High levels of vulnerable employment might lead to increased dependence on non-renewable resources and environmentally harmful energy sources, potentially obstructing sustainable development (Ofori et al., 2023).

Industrial activity (ind) measured by net industry value-added, including sectors such as manufacturing and construction, is also analyzed. While industry significantly contributes to economic growth, it simultaneously imposes substantial environmental burdens. Measuring industry's net value-added offers insights into balancing economic development objectives with environmental goals (Tsoy and Heshmati, 2024).

The study further integrates domestic capital investment or capital formation (inv), grounded in the Neoclassical Growth Model (Solow, 1956; Romer, 1986). Capital formation—investment in machinery, infrastructure, and equipment—boosts labor productivity and economic growth while enhancing technological capabilities and resource efficiency, thereby mitigating negative environmental impacts. Alongside FDI, domestic capital formation is essential to understanding the broader influence of economic investment on green growth.

Additionally, the Financial Development Index sourced from the World Bank's WDIs provides insight into the financial strength of countries. Strong financial systems facilitate investments in sustainable infrastructure and green technology adoption, significantly impacting environmental outcomes and advancing sustainable growth.

Globalization's role in green development is assessed through two additional variables: trade openness and remittances. Trade openness captures countries' integration into global markets, potentially enabling the transfer of advanced green technologies and higher environmental standards from developed nations (Grossman and Krueger, 1995). Remittances, the money sent home by overseas workers, represent vital financial resources supporting investments in sustainability activities and reducing pressure on natural resources (Goschin, 2014; Usman and Jahanger, 2021). In line with SDGs 8 (promoting sustained economic growth) and 10 (reducing inequality), remittances help to finance healthcare, education, and green technologies, improving livelihoods and environmental quality (Acheampong et al., 2021).

Lastly, renewable energy (renw) is identified as a crucial factor in achieving green and sustainable economies. Renewable energy effectively reduces greenhouse gas emissions, thus protecting the environment and contributing positively to economic growth (Couture et al., 2019; Canton, 2021). Although some research highlights possible negative impacts—such as increased CO_2 emissions from biomass (Ben Jebli et al., 2019)—the prevailing consensus emphasizes renewable energy's essential role in promoting sustainable development (Kahouli et al., 2014). This study specifically examines whether renewable energy use meaningfully advances green growth among Asian countries.

3.2. Methodology

3.2.1. Model design

The objective of this research is to analyze the impact of FDI on green growth in Asia. Therefore, the specifications of the empirical model are grounded on the premise that FDI plays a crucial role in promoting green growth by enhancing environmental sustainability indicators in economic activities (Ofori et al., 2023; Akram et al., 2020). Building on previous studies examining the relationship between FDI and environmental sustainability, we have refined the green economic growth model to align with the structure and characteristics of the Asian countries datasets as follows:

(2) GreenGDP = f (FDI, X)

where GreenGDP represents the GDP adjusted for the costs and losses associated with environmental degradation and natural resource depletion. Green GDP is endogenously determined by FDI and other determinants (X), including trade openness (trade), vulnerable employment (vulem), value added by industry share (ind), remittances (remit), capital formation (inv), financial development index (fin), and renewable energy (renw) generation. In this equation, we do not include GDP per capita as an explanatory variable, as it overlaps with GDP and its inclusion would bias the results and potentially introduce severe multicollinearity into the model.

We now turn to defining the binary environmental sustainability measure in alignment with the standards set forth by the SDGs. This follows the functional form proposed by Akram et al. (2020) and Ofori et al. (2023), as represented in the following formula:

(3) GHG = f (FDI, Z)

where GHG (Greenhouse Gas Emissions) reflects environmental sustainability, FDI represents foreign direct investment, and Z denotes the control variables in the model (similar to those in Equation (1) but with the addition of GDPP). We included GDPP in this model based on the hypothesis that as GDP per capita rises—indicating an increase in wealth—there may be implications for whether environmental sustainability can be sustainable or not.

Finally, following the theoretical model applied by Baek and Koo (2009) and Tsoy and Heshmati (2024), we specify Equation (4) to examine the environmental efficiency of Asian countries:

(4) EPI = f (FDI, Z)

where the Environmental Performance Index (EPI), developed by Yale University in the United States, serves to evaluate environmental health and ecosystem vitality. FDI represents foreign direct investment, and (Z) is the vector of our control variables listed in Equation (3).

It is worth to note that, in order to facilitate estimation and interpretation of the model, we have standardized the data by removing outliers and applying a logarithmic transformation to the following variables: Greenhouse Gas Emissions (GHG), FDI, GDP per capita (GDPP), Green GDP, remittances (remit), and capital formation (inv).

3.2.2. Pool OLS and FE and RE models

We use econometric methodology to achieve our research objectives. It is commonly used for describing the relationships among economic phenomena, as it specifies the relationships and transforms these phenomena into data that can be easily quantified and their relationships estimated. For convenience, we normalize the model by taking the log of certain variables. The logarithmic transformation generates estimated results that are directly interpreted as elasticities. Therefore, Equations (2), (3), and (4) can be rewritten as follows:

$$(5)\quad ln(GreenGDP_{it}) = \alpha_0 + \alpha_1 ln(FDI_{it}) + \alpha_2 Trade_{it} + \alpha_3 Vulem_{it} + \alpha_4 Ind_{it} + \alpha_5 ln(Remit_{it}) + \alpha_6 ln(Inv_{it}) + \alpha_7 Fin_{it} + \alpha_8 Renw_{it} + \delta_t + \pi_i + \epsilon_{it}$$

$$(6) \quad ln(GHG_{it}) = \beta_0 + \beta_1 ln(FDI_{it}) + \beta_2 Trade_{it} + \beta_3 Vulem_{it} + \beta_4 Ind_{it} + \beta_5 ln(Remit_{it}) + \beta_6 lnInv_{it} + \beta_7 Fin_{it} + \beta_8 Renw_{it} + \beta_9 ln(GDPP_{it}) + \delta_t + \pi_i + \epsilon_{it}$$

$$(7) \quad EPI_{it} = \gamma_0 + \gamma_1 ln(FDI_{it}) + \gamma_2 Trade_{it} + \gamma_3 Vulem_{it} + \gamma_4 Ind_{it} + \gamma_5 ln(Remit_{it}) + \gamma_6 ln(Inv_{it}) + \gamma_7 Fin_{it} + \gamma_8 Renw_{it} + \gamma_9 ln(GDPP_{it}) + \delta_t + \pi_i + \epsilon_{it}$$

where α, β, and γ represent the coefficients of the variables in each equation, with i denoting the country and t time. Additionally, the models incorporate year-fixed effects (δt) to control for common shocks that affect all countries in each period. Country-fixed effects (πi) are also included in the model to account for unobserved, country-specific factors that remain constant over time which could influence the research outcomes.

First, we apply a pooled Ordinary Least Squares (OLS) regression for panel data with 912 observations, followed by Fixed Effects (FE) and Random Effects (RE) models to conduct the empirical analysis. Then, we employ various tests to determine which model among these three estimation methods provides the best fit. The Breusch-Pagan Lagrange Multiplier (LM) test is used to check for the presence of random effects, with its results guiding the choice between the pooled OLS and the RE model. Additionally, we apply the F-test for fixed effects and the Hausman test to decide between the FE and RE models. The empirical results indicate that the FE model is the most appropriate for this study. According to Hausman and Taylor (1981), the FE model is often preferred because it controls for time-invariant factors across countries and provides consistent, robust estimates by minimizing errors from omitted variables and eliminating biases from unobserved values. This approach by combining both fixed and random effects is suitable for panel data, especially unbalanced panel data.

To ensure the accuracy of the estimation results, several diagnostic tests were conducted. First, we used the Variance Inflation Factor (VIF) to measure the degree of multicollinearity in the pooled OLS regression model. Next, we employed the Wooldridge test and the Breusch–Pagan test to check for the presence of heteroscedasticity and autocorrelation. The empirical results indicate that, although there is no evidence of severe multicollinearity (with all VIFs<5.0) in the three models, heteroscedasticity and autocorrelation were present. Therefore, robust standard errors were applied to adjust the model for obtaining more accurate results. However, the Fixed Effects (FE) model with robust standard errors can control for the time-invariant unobserved factors and address heteroscedasticity and autocorrelation. Nonetheless, there is no evidence to suggest that it can resolve the issue of endogeneity. This is a primary concern when measuring the impact of FDI on green growth, especially since the study uses country-level variables, which are likely to be endogenous due to omitted variable bias and reverse causality, leading to biased coefficient estimates. For this reason, a more advanced method, the System Generalized Method of Moments (System GMM), will be applied.

3.2.3. System Generalized Method of Moments Estimation (System GMM)

This study utilizes the GMM method to address common endogeneity challenges in dynamic panel data models—challenges especially pertinent when examining the interplay between FDI, economic growth, and environmental sustainability. As originally formulated by

Arellano and Bond (1991), GMM provides a robust solution to the problem of endogeneity, which often arises due to reciprocal causal relationships and omitted time-varying factors (Joekes, 1995; Roberts and Whited, 2013; Shahbaz et al., 2019). For instance, while FDI and trade openness can foster green growth through technology transfers, higher environmental standards in a host country may simultaneously attract more FDI, creating two-way causality. Failure to account for this feedback loop can yield biased or inconsistent estimates.

Beyond reverse causality, unobserved or latent variables—such as policy effectiveness, governance quality, or structural shifts in the economy—also contribute to endogeneity. These variables may simultaneously affect both environmental outcomes and macroeconomic indicators, complicating efforts to isolate FDI's true impact on green growth. Moreover, major global events like the 2008 financial crisis and the COVID-19 pandemic introduced external shocks that disproportionately affected FDI, GDP, and environmental indicators in Asian countries. Traditional estimation methods that ignore these complexities risk producing unreliable results.

To overcome these methodological constraints, the study employs the two-step System GMM approach advanced by Blundell and Bond (1998). This technique refines the one-step (first-difference) GMM by mitigating inefficiencies and data loss associated with differencing transformations. Specifically, Arellano and Bover (1995) proposed the forward orthogonal deviation method, which subtracts the average of available future observations instead of lagged observations. This adjustment preserves more data points and helps maintain exogeneity relative to country-specific fixed effects (Roodman, 2009). Consequently, the two-step System GMM estimator delivers more consistent and efficient results, particularly suitable for balanced panel datasets or dynamic models with high autocorrelation (Arellano and Bover, 1995; Blundell and Bond, 1998).

Under the System GMM framework, instrumental variables are drawn from both level and difference equations, enabling stronger control over fixed effects and endogeneity. This attribute proves especially advantageous when the number of cross-sectional units (countries) exceeds the length of the time series (Baltagi, 2008). Existing research confirms that System GMM yields more accurate estimates than simpler estimators like pooled OLS, primarily because it accounts for serial correlation and endogenous relationships through lagged instruments (Bond et al., 2001; Blundell and Bond, 1998).

Instrument validity in GMM is tested through the Hansen test, which checks for overidentifying restrictions, and the Arellano-Bond AR(2) test, which detects serial correlation in the error terms (Roodman, 2009). These diagnostic checks confirm whether the instruments are genuinely exogenous. Windmeijer (2005) further stresses the importance of small-sample corrections to two-step GMM's standard errors, demonstrating through Monte Carlo simulations that these corrections yield more accurate inferences. This adjustment addresses the downward bias in standard error estimates that can otherwise occur in finite samples (Windmeijer, 2005).

Another key consideration is instrument proliferation, wherein excessive instrument counts can inflate confidence intervals and distort coefficient estimates. In line with Roodman (2009), this study limits the number of instruments, thereby enhancing the robustness of the results. Because of these methodological strengths, two-step System GMM has become a mainstay in recent empirical analyses investigating dynamic relationships among economic variables (Chen et al., 2018; Sung et al., 2018; Ofori et al., 2022; Tsoy and Heshmati, 2024).

The two-step System GMM approach employed here effectively manages endogeneity by leveraging internal instruments derived from lagged observations, controlling for fixed effects, and accounting for autocorrelation. By incorporating rigorous diagnostic tests, small-sample corrections, and careful management of instrument proliferation, this study ensures that the estimated impact of FDI on sustainable development and green growth in Asia is both consistent and reliable. Consequently, policymakers can draw more accurate conclusions about the role of FDI in promoting environmental sustainability, reinforcing the significance of robust econometric techniques in informing policy decisions.

Based on the theories of the two-step System GMM, we transform equations (4), (5), and (6) using the two-step System GMM model with one lag as follows:

$$(7) \quad ln(GreenGDP_{it}) = \alpha_0 + \alpha_1 ln\left(GreenGDP_{i,t-1}\right) + \alpha_2 ln(FDI_{it}) + \alpha_3 Trade_{it} + \alpha_4 Vulem_{it} + \alpha_5 Ind_{it} + \alpha_6 ln(Remit_{it}) + \alpha_7 ln(Inv_{it}) + \alpha_8 Fin_{it} + \alpha_9 Renw_{it} + \delta_t + \pi_i + \epsilon_{it}$$

$$(8) \quad ln(GHG_{it}) = \beta_0 + \beta_1 ln\left(GHG_{i,t-1}\right) + \beta_2 ln(FDI_{it}) + \beta_3 Trade_{it} + \beta_4 Vulem_{it} + \beta_5 Ind_{it} + \beta_6 ln(Remit_{it}) + \beta_7 lnInv_{it} + \beta_8 Fin_{it} + \beta_9 Renw_{it} + \beta_{10} ln(GDPP_{it}) + \delta_t + \pi_i + \epsilon_{it}$$

$$(9) \quad EPI_{it} = \gamma_0 + \gamma_1 EPI_{i,t-1} + \gamma_2 ln(FDI_{it}) + \gamma_3 Trade_{it} + \gamma_4 Vulem_{it} + \gamma_5 Ind_{it} + ln(Remit_{it}) + \gamma_7 ln(Inv_{it}) + \gamma_8 Fin_{it} + \gamma_9 Renw_{it} + \gamma_{10} ln(GDPP_{it}) + \delta_t + \pi_i + \epsilon_{it}$$

Similar to equations (4), (5), and (6), time-fixed effects are incorporated in the model specification. When performing two-step GMM, we encounter challenges with finite samples, as GMM estimation can generate a large number of instruments, with the instrument count proportional to the square of the time dimension of the panel data (Roodman, 2009). This can lead to a situation where the number of instruments may be large relative to the number of data observations. Although there is limited research offering solutions to this issue, Windmeijer (2005) provides evidence suggesting that reducing the number of instruments can help lower the average bias in the two-step estimates of key parameters (Windmeijer, 2005; Roodman, 2009). Therefore, this study applies a strategy of limiting the lags used to create instruments and restricting their range of application.

Robustness Check with stepwise 2-step GMM

This study employs a stepwise regression model combined with the two-step GMM method to investigate the stability of the model and the influence of FDI on green growth indicators. The analysis begins by regressing three baseline equations, each with FDI as the sole independent variable, to assess its initial impact on GHG emissions, Green GDP, and EPI. Following Wooldridge (2010), control variables are then incrementally introduced to test whether FDI's effect remains significant and stable, thereby minimizing the risk of omitted variable bias.

The stepwise regression method, first proposed by Efroymson (1960), facilitates the systematic inclusion or exclusion of explanatory variables based on their statistical relevance. By sequentially adding variables, the approach helps isolate each factor's individual contribution to green growth, allowing for a clearer understanding of which variables exert a pronounced impact (Ofori et al., 2023; Farzanegan et al., 2021).

To effectively manage the diverse set of control variables, the study categorizes them into three groups—Highly Important, Important, and Less Important—based on two criteria: the degree of direct impact on environmental indicators (GHG, Green GDP, and EPI) and the consistency of empirical evidence reported in recent literature. Variables that exhibit a strong and direct influence on reducing emissions or enhancing environmental performance are classified as Highly Important (Paramati et al., 2017). The study emphasizes post-2019 research findings to ensure that the selected variables have contemporary relevance for green growth (Charfeddine et al., 2019).

The Highly Important group consists of trade openness, renewable energy, and industry value-added. Trade openness is recognized as a double-edged sword—it can increase emissions in certain sectors but also facilitate the transfer of clean technologies through enhanced global integration (Paramati et al., 2017). Renewable energy is pivotal for curbing emissions and improving environmental quality, supporting nations in aligning with global sustainability goals (Paramati et al., 2017; Zhang et al., 2017). Additionally, the industry sector, as a primary driver of economic growth, is key to understanding how FDI can provide the capital and technological advancements needed to reduce environmental footprints (Charfeddine et al., 2019).

The Important group includes GDP per capita and vulnerable employment. GDP per capita serves as a fundamental indicator of a country's developmental stage and its ability to invest in clean technologies and environmental improvements (Bytyqi et al., 2024). Meanwhile, vulnerable employment—particularly significant in developing economies—often correlates with informal activities that can lead to higher GHG emissions due to less regulated practices. Studies by the ILO (2020) highlight how precarious labor conditions may exacerbate environmental degradation, making this variable critical for understanding the broader implications of FDI on sustainability.

Lastly, the Less Important group comprises capital formation, remittances, and the financial development index. While these financial factors do influence economic development, their direct effect on green growth is generally more indirect or facilitative in nature (Charfeddine et al., 2019). For example, capital formation boosts overall investment levels, yet its impact on green growth is less pronounced compared to renewable energy or industrial structure improvements. Similarly, remittances tend to affect green initiatives at a household level rather than inducing systemic changes.

Overall, the stepwise regression approach, combined with the robust two-step GMM estimation, progressively clarifies the role of FDI in green growth. By monitoring how the FDI coefficient behaves as additional control variables are introduced, the model ensures that observed relationships reflect genuine effects rather than spurious correlations. This method supported by extensive empirical evidence, offers a comprehensive insight into FDI's contribution to environmental sustainability and economic development.

4. Empirical Result

4.1. Green GDP and FDI

Table 4 presents the results from examining the impact of FDI on Green GDP. Based on the results from the Breusch-Pagan/Cook-Weisberg test in Appendix Table A.1, with a p-value of 0.0000 < alpha (10%), we reject the null hypothesis (H0) of homoscedasticity and confirm the presence of heteroskedasticity in the model. To address this, all three models use robust standard errors to correct for heteroskedasticity. Additionally, the Variance Inflation Factor results show that the VIF of all variables is less than 5, with an average VIF of 2.38, indicating no serious multicollinearity in the model (Appendix Table A.2).

The main variable of the study, FDI, has a positive and statistically significant effect on the dependent variable in all three models, with the strongest effect observed in the OLS model (significant at the 1% level). This suggests that FDI plays a crucial role in influencing the Green GDP.

Furthermore, remittances (log_rem) and capital formation (log_inv) also show positive and statistically significant effects in all three models, highlighting the importance of remittances and domestic investment in influencing the research outcomes. In contrast, trade openness and vulnerable employment (vulem) exhibit negative coefficients, indicating small but statistically significant negative effects on the Green GDP. The coefficient for VULEM remains significant across all models, confirming the stable negative impact of vulnerable employment. Financial development (fin) and renewable energy (renw) show mixed results: FIN is significant only in the OLS model, while RENW has a weak or no effect in the FE and RE models.

Table 4. Estimation results for the effect of FDI on Green GDP

EXPLANATORY VARIABLES	OLS	FE	RE
LOG_FDI	0.326***	0.022*	0.031*
	(0.027)	(0.016)	(0.020)
TRADE	-0.014***	-0.002*	-0.003**
	(0.001)	(0.001)	(0.001)
VULEM	-0.005***	-0.016**	-0.013**
	(0.001)	(0.007)	(0.005)
LOG_REMIT	0.078***	0.088***	0.094***
	(0.014)	(0.027)	(0.029)
LOG_INV	0.359***	0.633***	0.631***
	(0.035)	(0.048)	(0.053)
FIN	2.941***	0.557	0.671

	(0.200)	(0.463)	(0.452)
RENW	0.009***	-0.001	0.001
	(0.001)	(0.004)	(0.004)
CONS	-12.720***	-12.260***	-12.750***
	(0.397)	(1.094)	(0.957)
N	779	779	779
R-SQUARED	0.924	0.805	0.823
Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.			

Although the OLS model reports a high R-squared (92.44%), the results from OLS may be biased due to the inability to control for unobserved differences between sample countries. The Hausman test (Appendix Table A.3) shows a p-value of 0.0000 < alpha (10%), leading to reject the null hypothesis (H0): "No systematic difference in coefficients between FE and RE models." This indicates that the difference in coefficients between the FE and RE models is systematic, and the Fixed Effects (FE) model is the more appropriate choice. Therefore, the FE model is selected as the main model. The use of robust standard errors in the FE model helps to address issues related to time-invariant unobserved factors, heteroskedasticity, and autocorrelation.

However, the FE model does not fully resolve the issue of endogeneity, which may arise from reverse causality or omitted variables. As a result, we use the two-step GMM method to address endogeneity and provide more accurate estimates of the relationship between FDI and the dependent variable. In addition, we use stepwise regression for the two-step GMM model to assess the stability of the model (robustness check), with the results presented in Table 5.

The results in Table 5 indicate that Foreign Direct Investment (FDI) has a consistently positive and significant effect on Green GDP across all specifications, with estimated coefficients ranging from 0.124 to 0.155 at the 1% significance level. This finding underscores FDI’s potential to enhance Green GDP through channels such as technological innovation and cleaner production processes (Shahbaz et al., 2013). However, trade appears to exert a negative influence on Green GDP, with coefficients between -0.0018 and -0.0069. These estimates, significant at the 5% to 1% levels, suggest that expanding trade can harm sustainable development, particularly if it involves energy-intensive or polluting goods without sufficient environmental regulations (Anderson and Strutt, 2000).

Regarding renewable energy (renw), its effect on Green GDP varies across models. Although some specifications (Columns 4 and 5) show a positive and significant coefficient, others do not. This inconsistency may stem from uneven adoption rates of renewable technologies or continued reliance on fossil fuels in certain Asian economies (Sadorsky, 2009; Apergis and Payne, 2010). Capital formation (log_inv) exhibits a positive and sometimes significant impact on Green GDP, with coefficients of 0.171 and 0.218 in Columns 7 and 8. This aligns with research suggesting that investments in modern and efficient infrastructure can foster sustainable development (Grossman and Krueger, 1995).

Table 5. GMM results for estimation of the effect of FDI on Green GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOG_GREENGDP (-1)	0.822***	0.803***	0.798***	0.816***	0.798***	0.544***	0.596***	0.485***
	(0.051)	(0.053)	(0.058)	(0.050)	(0.051)	(0.158)	(0.118)	(0.133)
LOG_FDI	0.131***	0.153***	0.153***	0.140***	0.153***	0.155***	0.128***	0.124***
	(0.035)	(0.040)	(0.042)	(0.037)	(0.038)	(0.049)	(0.032)	(0.030)
TRADE		-0.002**	-0.002**	-0.002*	-0.002**	-0.003**	-0.004**	-0.007***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
RENW			-0.001**	0.000	0.002	0.006*	0.003	0.006**
			(0.002)	(0.001)	(0.002)	(0.003)	(0.002)	(0.003)
IND				0.003*	0.003	0.002	0.005	0.012***
				(0.002)	(0.002)	(0.003)	(0.004)	(0.005)
VULEM					-0.002	-0.004*	-0.002	-0.000
					(0.003)	(0.002)	(0.002)	(0.002)
LOG_INV						0.265	0.218*	0.171*
						(0.168)	(0.121)	(0.092)
LOG_REMIT							0.018	0.0641**
							(0.019)	(0.029)
FIN								1.904***
								(0.656)
CONS	-1.995***	-2.214***	-2.181***	-2.120***	-2.221***	-7.369**	-6.346***	-6.370***
	(0.575)	(0.645)	(0.716)	(0.634)	(0.668)	(2.918)	(2.159)	(1.820)
OBSERVATIONS	835	835	835	835	835	835	749	749
AR(1)	0	0	0	0	0	0.005	0.002	0.003
AR(2)	0.112	0.14	0.14	0.101	0.14	0.19	0.204	0.201
HANSEN P-VALUE	0.186	0.143	0.145	0.197	0.189	0.181	0.282	0.13
WALD STATISTIC	10675.62	12618.59	10604.36	20681.11	14213.91	41032.17	50976.92	70611.51
WALD P-VALUE	0	0	0	0	0	0	0	0

Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.

Vulnerable employment negatively affects Green GDP, as indicated by coefficients ranging from -0.00235 to -0.00431 (significant at the 10% level). High levels of precarious or informal employment often correlate with unsustainable growth and environmental degradation, highlighting the importance of stable labor conditions for fostering long-term sustainability (ILO, 2016). Remittances, by contrast, have a positive impact on Green GDP, with coefficients of 0.0184 in Column 7 and 0.0641 in Column 8 at the 5% significance level. These findings support the argument that remittances can enhance living standards and fund environmentally friendly projects, particularly in developing nations (Meyer and Shera, 2017). Meanwhile, industry value-added (ind) also shows a positive coefficient of 0.0118 (1% significance) in Column 8, suggesting that fostering clean industrial activities can boost Green GDP and generate sustainable employment (Szirmai, 2012).

Financial quality (fin) similarly demonstrates a strong positive effect on Green GDP, with a coefficient of 1.904 at the 1% level in Column 8. This result underscores the role of developed financial systems in channeling resources toward green investments, aligning with Beck et al. (2007), who emphasize that well-functioning financial institutions are critical for financing sustainable innovations.

Robustness checks, including AR(1), AR(2), and Hansen tests, reveal no endogeneity or serial correlation concerns, affirming the reliability of the model specification. The p-values from Hansen tests exceed 0.1, confirming instrument validity, while the Wald statistic indicates high overall significance. Taken together, these findings suggest that FDI, along with certain macroeconomic and structural factors, can meaningfully contribute to Green GDP, provided that complementary policies and financial mechanisms are in place to support sustainable development.

4.2. Greenhouse gas emission and FDI

Table 6 presents the regression results estimated by OLS, FE, and RE methods examining the relationship between FDI and GHG emissions. According to the Breusch-Pagan/Cook-Weisberg test results in Appendix Table A.1, it indicates the existence of heteroskedasticity in the model. To account for this, robust standard errors are applied in all three models to correct for heteroskedasticity. Moreover, the Variance Inflation Factor (VIF) results suggest that multicollinearity is not a concern in the model (Appendix Table A.2).

Table 6. Estimation of the effect of FDI on GHG emission

EXPLANATORY VARIABLES	OLS	FE	RE
LOG_FDI	0.367***	-0.006	-0.005
	(0.033)	(0.012)	(0.012)
LOG_GDPP	-0.721***	0.058	0.012
	(0.049)	(0.052)	(0.051)
TRADE	-0.013***	-0.001	-0.001
	(0.001)	(0.001)	(0.000)

VULEM	-0.004**	-0.007*	-0.006
	(0.002)	(0.004)	(0.004)
LOG_REMIT	-0.080***	0.004	0.007
	(0.020)	(0.019)	(0.020)
LOG_INV	0.392***	0.123**	0.158***
	(0.044)	(0.046)	(0.048)
FIN	1.974***	0.197	0.255
	(0.275)	(0.274)	(0.273)
RENW	-0.013***	-0.012***	-0.012***
	(0.002)	(0.004)	(0.004)
CONS	2.906***	8.921***	8.211***
	(0.618)	(0.829)	(0.870)
N	779	779	779
R-SQUARED	0.820	0.342	0.427
Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.			

Although the OLS model shows a high R-squared, it may be biased by not accounting for unobserved country heterogeneity. The Hausman test suggests that the Fixed Effects (FE) model is preferable, but FE alone does not resolve endogeneity issues like reverse causality and omitted variables bias. Therefore, we use the two-step GMM approach, with stepwise regression results shown in Table 7.

Table 7 reveals that FDI has a significant positive impact on GHG emissions, with coefficients between 0.00506 and 0.0273 (5% or 1% significance). This indicates that increased FDI correlates with higher emissions, likely due to the expansion of pollution-intensive sectors (Acharyya, 2009; Wang and Chen, 2014). Notably, these findings contrast with Table 5, where FDI boosts Green GDP, suggesting that FDI’s environmental impact varies by sector, technology adoption, and production scale. Additionally, including macroeconomic factors intensifies FDI’s effect on GHG emissions (Cole et al., 2014).

Table 7. GMM results for the effect of FDI on GHG emission

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LOG_GHG (-1)	0.977***	0.988***	0.991***	0.986***	0.955***	0.957***	0.952***	0.932***	0.952***
	(0.0126)	(0.0099)	(0.0109)	(0.0107)	(0.0142)	(0.0134)	(0.0211)	(0.0299)	(0.0333)
LOG_FDI	0.0105*	0.0064	0.00506	0.00827	0.0273***	0.0258***	0.0178**	0.0187***	0.0135**
	(0.0055)	(0.0055)	(0.0055)	(0.0054)	(0.00876)	(0.0082)	(0.0077)	(0.0056)	(0.0065)
TRADE		-0.00011	-0.00009	-0.00013	-0.00034**	-0.00032**	-0.00021*	-0.00054**	-0.00048
		(0.00009)	(0.00012)	(0.0001)	(0.00016)	(0.00015)	(0.00011)	(0.00027)	(0.00036)
RENW			0.000011	0.00019	-0.00066	-0.00067	-0.00017	-0.00034	-0.00033
			(0.00016)	(0.00018)	(0.00045)	(0.00051)	(0.00055)	(0.00076)	(0.00055)
IND				0.00073***	0.00185**	0.00181**	0.0017***	0.00257***	0.00243**
				(0.00023)	(0.00076)	(0.00072)	(0.00055)	(0.0008)	(0.00120)
LOG_GDPP					-0.0253**	-0.0215**	-0.0329*	-0.0469*	-0.0398
					(0.0105)	(0.00919)	(0.0186)	(0.0259)	(0.0270)
VULEM						0.000216	-0.00027	-0.00049	-0.00016
						(0.00064)	(0.00066)	(0.00077)	(0.00046)
LOG_INV							0.0215	0.0356	0.0195
							(0.0179)	(0.0300)	(0.0216)
LOG_REMIT								-0.00204	-0.00071
								(0.00641)	(0.0046)
FIN									0.109
									(0.100)
CONS	0.0704	0.0391	0.0334	0.000396	0.160*	0.131	-0.0540	-0.00442	0.116
	(0.0705)	(0.0376)	(0.0436)	(0.0459)	(0.0972)	(0.0921)	(0.0917)	(0.105)	(0.125)
N	835	835	835	835	835	835	835	749	749
AR(1)	0	0	0	0	0	0	0	0	0
AR(2)	0.227	0.191	0.183	0.185	0.276	0.269	0.241	0.246	0.215
Hansen p-value	0.086	0.076	0.073	0.088	0.243	0.223	0.169	0.204	0.183
Wald statistic	5.03E+06	1.04E+07	1.33E+07	1.39E+07	3.15E+06	3.82E+06	7.40E+06	5.43E+06	9.52E+06
Wald p-value	0	0	0	0	0	0	0	0	0
Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.									

Trade emerges as a negative determinant of greenhouse gas (GHG) emissions in most models, with coefficients between -0.000336 and -0.000536 (significant at 5% or 1%). This finding suggests that trade liberalization may reduce emissions by facilitating cleaner technologies or relocating polluting industries to regions with stricter environmental regulations (Antweiler et al., 2001). Nonetheless, trade negatively impacts Green GDP in Table 5, illustrating its dual role in economic and environmental outcomes (Grether et al., 2009).

Industrial value-added (ind) exhibits a positive and significant effect on GHG emissions, with coefficients ranging from 0.000734 to 0.00257 at the 1% or 5% levels. This indicates that industrial expansion contributes to higher emissions through energy-intensive production, in line with Liu et al. (2019). Meanwhile, renewable energy (renw) generally shows no significant influence on GHG emissions, implying that current renewable adoption has yet to offset reliance on fossil fuels (Sadorsky, 2009). In Table 5, renewable energy also lacks a consistent effect on Green GDP, reflecting uneven progress in transitioning to cleaner energy sources across the region.

Remittances and capital formation, both of which positively affect Green GDP in Table 5, do not significantly impact GHG emissions here. This discrepancy implies that while these factors may foster sustainable development through improved living standards or green infrastructure, they do not directly curtail emissions (Meyer and Shera, 2017; Grossman and Krueger, 1995).

Diagnostic checks confirm the robustness of the results. The AR(1) test rules out first-order autocorrelation, and the AR(2) test shows no severe second-order correlation. Hansen test p-values exceed 0.1 in all models, validating instrument choice, and highly significant Wald statistics ($p < 0.01$) indicate that the independent variables collectively explain a substantial share of the variation in GHG emissions.

4.3. Environment Performance Index and Foreign Direct Investment

Table 8. Estimation of the effect of FDI on EPI

EXPLANATORY VARIABLES	OLS	FE	RE
LOG_FDI	-2.544***	0.501	0.310
	(0.502)	(0.598)	(0.596)
LOG_GDPP	3.192***	-5.833	-2.904
	(0.953)	(4.374)	(2.996)
TRADE	0.104***	-0.000715	0.0120
	(0.0172)	(0.0496)	(0.0465)
VULEM	0.0454	-0.123	-0.127
	(0.0377)	(0.259)	(0.186)
LOG_REMIT	-0.595	-0.575	-0.991
	(0.381)	(1.120)	(0.796)
LOG_INV	-3.751***	-2.701	-4.276***

	(0.598)	(2.576)	(1.634)
FIN	-18.61***	-18.30	-18.75
	(4.184)	(17.71)	(14.93)
RENW	0.0243	0.00556	0.00915
	(0.0379)	(0.235)	(0.194)
CONS	147.6***	146.5***	172.1***
	(13.41)	(51.58)	(38.16)
N	778	778	778
R-SQUARED	0.5734	0.3666	0.4857
Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.			

Table 8 presents the regression results of the OLS, FE, and RE models examining the relationship between FDI and EPI. The Breusch-Pagan test indicates heteroskedasticity, so robust standard errors are employed. The VIF values show no multicollinearity. The Hausman test confirms that the FE model is more appropriate than the RE model; however, the issue of endogeneity remains, which the FE model cannot address. To overcome this limitation, a two-step GMM approach is applied, alongside stepwise regression to check for robustness, with the results presented in Table 9.

The results in Table 9 reveal that FDI has a consistently negative effect on the EPI, with coefficients ranging from -0.977 to -1.139, statistically significant at the 5% and 1% levels (Columns 2, 3, 5, 6). This implies that FDI may diminish environmental efficiency, likely due to investments favouring short-term profits in energy-intensive and polluting industries rather than promoting green technologies. These findings echo those of Moudatsou and Apostolakis (2015), Yang et al. (2020), and Hossain et al. (2021), which suggest that FDI can worsen environmental pollution when environmental safeguards are weak.

In contrast, Table 5 showed that FDI boosts Green GDP (coefficients from 0.124 to 0.155, significant at the 1% level), while Table 7 indicates that FDI increases GHG emissions. This contrast underscores FDI’s conflicting impacts—improving economic outcomes through green investments on one hand yet exacerbating pollution through its support of energy-intensive industries on the other.

Trade, on the other hand, exerts a positive influence on EPI, with coefficients between 0.0150 and 0.0269 (significant at the 1% to 5% levels). This suggests that trade liberalization may facilitate the transfer of clean technologies and environmentally friendly products (Antweiler et al., 2001). The effect of renewable energy on EPI is generally insignificant, indicating an uneven transition toward renewable sources, possibly due to high initial costs and limited policy support (Krauss, 2020).

Table 9. GMM estimation of the effect of FDI on EPI

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
EPI (-1)	0.794***	0.783***	0.795***	0.785***	0.809***	0.804***	0.825***	0.804***	0.836***
	(0.0657)	(0.0661)	(0.0650)	(0.0710)	(0.0655)	(0.0620)	(0.0558)	(0.0528)	(0.0403)
LOG_FDI	-0.977**	-1.139***	-0.976**	-1.078**	-1.025***	-1.026***	-0.547	-0.683**	-0.605**
	(0.401)	(0.388)	(0.379)	(0.422)	(0.394)	(0.395)	(0.335)	(0.288)	(0.259)
TRADE		0.0239***	0.0247***	0.0269***	0.0222***	0.0225***	0.0150**	0.0197	0.0182**
		(0.00715)	(0.00708)	(0.0078)	(0.0077)	(0.0075)	(0.0060)	(0.0121)	(0.00902)
RENW			0.0251	0.0137	0.0283	0.0330	0.0151	0.0130	0.0141
			(0.0187)	(0.0212)	(0.0203)	(0.0230)	(0.0213)	(0.0183)	(0.0165)
IND				-0.0400	-0.0481*	-0.0485*	-0.0451**	-0.0622*	-0.0661**
				(0.0288)	(0.0270)	(0.0266)	(0.0227)	(0.0318)	(0.0332)
LOG_GDPP					0.546	0.429	0.781	1.181***	1.315***
					(0.388)	(0.436)	(0.541)	(0.458)	(0.431)
VULEM						-0.0118	0.0104	0.0234	0.0178
						(0.0258)	(0.0273)	(0.0242)	(0.0197)
LOG_INV							-0.549	-0.678	-0.294
							(0.460)	(0.491)	(0.365)
LOG_REMIT								-0.0243	-0.0224
								(0.233)	(0.219)
FIN									-4.317*
									(2.563)
CONS	24.51**	26.11***	21.74**	25.66**	19.81**	21.27**	20.86**	24.13**	13.57*
	(9.847)	(9.204)	(9.035)	(10.85)	(10.10)	(9.319)	(10.55)	(10.71)	(8.050)
N	833	833	833	833	833	833	833	747	747
AR(1)	0.087	0.087	0.088	0.088	0.087	0.087	0.087	0.042	0.039
AR(2)	0.535	0.541	0.538	0.545	0.54	0.541	0.544	0.822	0.815
HANSEN P VALUE	0.373	0.438	0.44	0.425	0.413	0.408	0.405	0.571	0.537
WALD STATISTIC	2139.2	2530.83	3169.42	2956.92	3724.41	3944.12	5877.18	8539.49	21645.63
WALD P VALUE	0	0	0	0	0	0	0	0	0
Note: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses.									

Additionally, industrial value-added negatively impacts EPI (-0.0481 to -0.0661, significant at the 5% or 10% level), indicating that industrial activities in energy-intensive sectors reduce environmental efficiency. GDP shows a positive effect on EPI (0.429 to 1.315, significant at 1%), suggesting that economic growth can support environmental initiatives if paired with strong policies (Shahbaz et al., 2013). Lastly, financial quality negatively affects EPI (-4.317, significant at 10%), implying that underdeveloped financial systems hinder green investments (Mensi et al., 2021; Baloch et al., 2022).

5. Discussion of the Results

The relationship between FDI and green growth in Asia reveals a complex, non-contradictory phenomenon influenced by the region's diverse socio-economic structures, investment priorities, and regulatory frameworks. On one hand, FDI is a vital source of capital that boosts Green GDP through improved infrastructure, enhanced production capacity, and technology transfer. Such inflows stimulate renewable energy projects, energy efficiency, and eco-friendly industrial advancements, all of which contribute to green economic development.

However, this positive economic impact does not guarantee environmental sustainability. Many Asian countries lack stringent environmental regulations, and rapid economic expansion often takes precedence over ecological concerns. As a result, FDI inflows—especially those directed toward heavy industries, energy-intensive sectors, and manufacturing hubs—tend to raise GHG emissions and deteriorate environmental quality, as reflected by declines in the EPI. Empirical evidence shows that while FDI positively affects Green GDP, it simultaneously increases GHG emissions and reduces EPI. This paradox suggests that despite efforts to attract sustainable FDI projects, the implementation may inadvertently lead to environmental harm if economic growth fails to account for environmental costs (Sarkodie and Strezov, 2019).

To further elaborate, Green GDP is an adjusted measure of economic output that considers environmental degradation. Although countries may experience growth in Green GDP through increased production and job creation, if this growth is driven by polluting industries, GHG emissions may continue to rise. For example, auxiliary regressions reveal that a 1% increase in FDI correlates with a 0.002% rise in GDP growth and a 0.00089% increase in Green GDP, suggesting that economic benefits can overshadow environmental costs.

In practice, many FDI projects in Asia are aimed at producing environmentally friendly goods, boosting Green GDP; yet they often lack sufficient measures to curb emissions. Studies by Badran et al. (2020) and Zhang et al. (2023) note that FDI frequently concentrates on energy-intensive or polluting industries, while Shahbaz et al. (2022) point out that the high cost of adopting green technologies prevents a full transition to clean production. Moreover, Wu et al. (2021) show that Green GDP growth may not coincide with reductions in GHG emissions if the environmental costs of unsustainable activities are not fully integrated into economic measurements.

Adding another layer, the Environmental Kuznets Curve (EKC) theory suggests that early economic development typically accompanies increased pollution until a certain income level is reached. Many Asian countries remain in this "ascending" phase, where FDI fuels growth but also intensifies environmental pressures. Industrial structure plays a crucial role; as Liu et al. (2023) found, FDI enhances Green GDP when it targets clean technology sectors. Conversely, when FDI is directed toward extractive or resource-intensive industries, the economic gains are often offset by significant environmental degradation.

Ultimately, FDI acts as a double-edged sword in Asia. While it brings capital and growth opportunities, it can also increase emissions and lower environmental performance if not managed with robust policies. Enforcing higher environmental standards, encouraging investment in green industries, and implementing carbon taxes are critical strategies to mitigate FDI's negative impacts. Achieving a sustainable balance requires coordinated efforts from governments, businesses, and the international community.

6. Conclusion and Policy Recommendations

The results show that while FDI positively influences Green GDP growth in Asia, it also contributes to higher GHG emissions and lower EPI scores. This duality reflects the tension between rapid economic expansion and environmental protection, where many developing economies prioritize short-term growth over sustainability. Nevertheless, FDI remains a valuable source of capital, underscoring the importance of implementing policies that balance economic gains with environmental safeguards.

According to the Environmental Kuznets Curve (Grossman and Krueger, 1995), pollution tends to rise in early development stages, eventually declining once countries attain sufficient income to invest in cleaner technologies. To meet the United Nations' SDGs—particularly Goals 8, 9, and 13—governments must enforce robust environmental regulations that steer FDI toward green and sustainable sectors. Wu et al. (2021) note that Green GDP can not grow without simultaneous emissions increase when policies are weak, while Shahbaz et al. (2022) find that countries with stricter regulations better channel FDI into clean technologies and reduce negative environmental impacts.

Policymakers can encourage green FDI through measures such as tax incentives, subsidies for R&D, and direct financial support for renewable energy and eco-friendly industries. Effective environmental monitoring is also essential to ensure compliance. Tang et al. (2016) suggest that carbon taxes and emissions limits can mitigate FDI's environmental harms, especially in heavily polluting industries. Additionally, regional and international collaboration can foster unified legal frameworks, sharing of clean technologies, and support for sustainable development initiatives (Liu et al., 2023). Corporate social responsibility (CSR) and public awareness are also equally vital. Wang and Dong (2019) emphasize that firms with strong CSR commitments contribute more positively to mitigating adverse environmental consequences. By integrating such efforts, countries can harness FDI for green development while curbing ecological costs, moving closer to global sustainability targets.

Despite offering important insights, this study has several limitations. First, it relies on aggregated regional data, which may obscure country-specific variations. Future research could focus on comparative case studies to uncover how distinct policy contexts shape FDI's environmental outcomes. Second, while this work concentrates on quantitative measures like

Green GDP and GHG emissions, qualitative dimensions (e.g., public perceptions or cultural attitudes) remain underexplored. Including these perspectives could yield a more nuanced understanding of sustainability challenges. Finally, the evolving global economic environment, driven by technological progress and shifting geopolitical landscapes, necessitates longitudinal research that tracks FDI's impact over time. Future inquiries should also investigate emerging green financial tools, such as green bonds and climate funds, to determine how they can complement policy efforts in steering FDI toward sustainable development goals.

APPENDIX

Table A.1. Breusch–Pagan/Cook–Weisberg test for heteroskedasticity

MODEL	P-VALUE	CHI-SQUARE
GREEN GDP MODEL	0.0000	61.28
GHG MODEL	0.0000	130.27
EPI MODEL	0.0000	93.42

Table A.2. Variance inflation factor (VIF)

VARIABLES	VIF	1/VIF
LOG GDPP	4.057	0.246
LOG INV	3.470	0.288
FIN	3.223	0.310
VULEM	3.198	0.313
LOG FDI	2.715	0.368
RENW	2.440	0.410
LOG REMIT	1.975	0.506
TRADE	1.227	0.815
MEAN VIF	2.788	.

Table A.3. The impact of change in FDI on change in GDP and Green GDP over year

VARIABLES	GDPYOY1	GREENYOY1
FDIYOY1	0.00200***	0.000891*
	(0.000212)	(0.000477)
CONS	7.634***	7.013***
	(0.429)	(1.142)
N	874	874
Notes: * p<0.1, ** p<0.05, *** p<0.01. Robust standard errors in parentheses. gdpyoy1, greenyoy1, fdiyoy1 are GDP per capita grow rate, Green GDP per capita grow rate and FDI grow rate over year (%).		

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