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Green Economy and Sustainable Growth: An Empirical Analysis of Selected Countries

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ABSTRACT

This study investigates the impact of the green economy on sustainable economic growth in twenty-two selected Asian countries from 1990 to 2023. The research focuses on countries identified by the Asia Pacific Accreditation Cooperation Incorporated (APAC) as leading markets in renewable energy, likely due to increasing investment in renewable energy development. Using data from the World Development Indicators (WDI). The research aims to determine the extent to which green economy factors contribute to sustainable economic growth in these Asian countries. The Autoregressive Distributed Lag (ARDL) model results revealed a significant positive relationship between CO_2 emissions, FDI, and GDP. Non-renewable energy production showed a negative impact on GDP. Interestingly, renewable energy consumption exhibited a significant negative relationship with GDP. The Westerlund Cointegration Test confirmed long-run relationships among the variables of this study. To promote sustainable growth, policymakers should encourage FDI while balancing environmental concerns, investing in efficient renewable energy technologies, and creating awareness about sustainable practices. Further research is needed to understand the complex dynamics between renewable energy consumption and economic growth in different contexts.

Keywords: Green economy, Sustainable economic growth, CO_2 emissions, Renewable energy, Non-renewable energy, Foreign Direct Investment (FDI), ARDL model, Westerlund Cointegration Test, GDP growth, Environmental policy.

Introduction

Green economy as an economy that improves the well-being of its people and society and reduces environmental costs and environmental risks. Change towards a green economy is a crucial development goal that seeks to minimize ecological deficits and other risks affecting the earth's environment on one hand and enhance social welfare and human possibilities on the other (UNEP, 2011). This model is needed to study its impact on sustainable economic

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growth in all the different countries, especially about the destruction of the environment and the climate change crisis (Kasztelan, 2017). Governments of countries enhance awareness that long-term economic development does support and complement the sustainability of biodiversity and resources; the green economy aspires to realize growth that reflects the economy and the conservation of resources (Aghion et al., 2009).

The old model of economic growth has been disastrous to the environment and hence, there has been an adoption of the green economy that tries to minimize resource consumption and pollution (Wani et al., 2024). That means the growth of the economy cannot occur with the exponential increase in the emissions of CO_2, which requires the energy transition towards low carbon sources (Dinda, 2004; Stern, 2007). Solar and wind energy are therefore suitable choices due to the long-term energy sources, since they eliminate the environmental hazards of fossil energy sources (Hacıimamoğlu and Sungur, 2024). Renewable energy also creates employment opportunities and that results in the advancement of technologies crucial for the growth of the economy (Chen et al., 2022).

Asian cities have become even more concerned with the sustainable development process to enhance the quality of life, sharpen the efficiency and environmental sustainability, and better integrate public transportation systems (Yigitcanlar et al., 2019). Renewable energy and sustainability investment has revealed good potential in the aspect of economic returns despite the finance issue and technology transfer. Working with the concept of sustainable economy, the interest is in the idea of green economy where efficiency of resource use and generation of renewable energy is looked at for long term economic growth (Barbier, 2011). The previous energy sources have fostered economic development, nonetheless, the use of fossil fuels contains some impacts as to the pricing challenges, more so from the political instability around the world. Viability can increase predictability in economic environments in developing nations with minimal resources, which make up its focus on renewable energy (Park, 2017). Nevertheless, there is still more work to be done regarding the link between RE consumption and economic development, especially in the context of the so-called developing nations (Shahbaz et al., 2021).

In this context, the objectives of the current Study are to determine the level of correlation between Green Economy Initiatives and the growth of GDP. And to assess the renewable and non-Renewable Energies in selected Asian countries. Further the study provides literature review, data and methodology, Results and discussion and Conclusion in next sections respectively.

Literature Review

This integrated theoretical review engulfs a broad literature that reviews theories to analyze all possible interplays between the GE, SD and several economic indicators in the different regions of the world. Houssam et al. (2023) aver that the green economy triggers a country's GDP and employment besides eradicating poverty in the developing nations. In their recommendations, they also point to the need to synchronously engage both the public and private actors to promote sustainable development. On the other hand, Chen et al. (2023) opine that developing countries suffer from green recovery initiatives in terms of GDP, yet the developed countries retain faster green growth implying the differentiated impact of development.

Chang et al (2023) concluded that renewable energy and sharing economy are indeed the

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prerequisites for sustainable economic growth in China. They discover that green energy use, share economy consumers, and foreign direct investment are associated, and, therefore, they can help to establish the formation of policy required for sustainable development. On the occurrence of Saudi Arabia, the importance of the blue economy variables is investigated by Waheed et al. (2023) to reveal that the development in the sea business and tourism will lead to improved long-term economic growth. Let it be noted that the above developmental factors can be associated with the need to integrate the 2030 Agenda into the current context.

In the study by Tan et al. (2023), the changes in China's green economic growth due to climate change are discussed, especially its regions; it shows that green economic growth has been gradually receiving more attention and is expected to increase in the western areas. According to the conclusions made, green finance and environmental law are crucial in promoting green economy. The study by Iqbal et al., (2022) investigates the determinants of renewable energy generation in Pakistan and shows a positive correlation between renewable energy production and the increment in the GDP over the years. This points to the fact that renewable resources have a positive implication to the economic growth of a country.

Ma et al. (2023) investigate the relationship between green financing, renewable energy investments, and G-20 environmental performance. According to them, there should be improved green financing for both developed and developing countries for improved environmental performance. Xu et al. (2023) attempt to investigate the relationship between green bonds and sustainable economic growth, the concept established by them reveals that even though green bonds foster sustainable development, the improvement depends on the utilization of the economy.

Moreover, the following literature review supports the need for proper governance and regulations as the key ingredient to sustainability. Specifically, it discusses environmental regulatory, institutional quality, and the technological factors which are related to ecological sustainability. The outcome presenting information about the resource curse recommends a moderation approach to balance development and resource exploitation to avoid the consequences of the curse, relying on policies that include renewable energy and environmental technologies, as well as solutions, which advance the cause of financial inclusion. Altogether, these studies show that building a viable GEM is a crucial priority for enhancing environmental outcomes and for continued and sustainable economic growth in various economies.

Materials and Method

Data

The econometric analysis shall involve using GDP as the dependent variable while CO_2 emissions, Renewable energy production, Non-renewable energy production, Renewable energy consumption, Non-renewable energy consumption, Unemployment, Foreign Direct Investment, and Inflation as independent variables; the independent variables shall be sorted as follows. All the following variables have been collected from World Development Indicator (WDI) in 22 selected Asian countries in the timeline of 1990 to 2023. Thus, the countries have been selected based on the report by Asia Pacific Accreditation Cooperation Incorporated (APAC), they are market leaders in renewable energy, due to funding to renewable energy projects.

Descriptive statistics show an important variability in the sampled countries regarding

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economic and environmental indicators. On the average 11,348.22, 96.7193 – 178,868.8 GDP per capita, the income levels vary and the standard deviation of 15,928.24 indicates high income variations in this country (WDI, 2023). The mean of CO_2 emissions is at 544,862.6 units, and the minimum is 938.8, and the maximum of 10,900,000, indicating wide differences in environmental impact and industrial activities. This also shows just how variable 1,528,173 is across the countries. The mean of Renewable Energy Production is 1.797207 kWh, with a range from 0.0002956 to 25.67013, suggesting that there are still some nations that are in the beginning stages of renewable energy production, with standard deviation of 3.909761.

The total of Non-Renewable Energy Production averages 76.22664 kWh with the minimum of 0.0263366 kWh and the maximum of 100 kWh, the spread of reliance on nonrenewable sources is a wide spectrum, and there is a standard deviation of 23.81276.

Table 1: Descriptive Analysis

Variable name	Mean	Min	Max	SD
GDP per Capita Current	11348.22	96.7193	178868.8	15928.24
CO_2 emissions	544862.6	938.8	1.09e+07	1528173
Renewable Energy Production	1.797207	.0002956	25.67013	3.909761
Non-Renewable Energy Production	76.22664	.0263366	100	23.81276
Renewable Energy Consumption	25.48762	0.001	95.12	26.35604
Non-Renewable Energy Consumption	2366.87	114.9325	11694.92	2646.624
FDI	1.32e+10	-2.60e+10	3.44e+11	3.63e+10
Inflation	8.27345	-2.314972	105.215	14.80947
Unemployment	5.402885	.116	21.211	3.883214

The Mean of Renewable Energy Consumption is 25.48762 between 0.001 to 95.12 and varies with a Standard Deviation of 26.35604. Non-Renewable Energy Consumption has an Average of 2366.87, with a range of 114.9325 to 11469.92 and very high standard deviation of 2,646.624, indicative of some diverging patterns of consumption of this resource.

Mean of Foreign Direct Investment (FDI) is given as 1.32e+10 USD with min = - 2.60e+10 and max = 3.44e+11, accounting for high variation in investment flows (SD= 3.63e+10). The inflation is from -2.314972 to 105.215 with an average of 8.27345, and a standard deviation of 14.80947, which means there are a lot of economic fluctuations. Finally, the data indicates an unemployment average of 5.402885%, a minimum between 0.116 and maximum of

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21.211, a standard deviation of 3.883214 that indicates large variation in unemployment rates (WDI, 2023).

Methodology

Cross Sectional Dependency:

The cross-sectional dependence problem (CD) needs to be dealt with when we have obtained unbiased estimation of panel data analysis. Differences, consequently, also lead to effects in the form of externalities induced by interrelatedness, by differences in the geographical or by unobserved common factors of origin. The functional estimation of Pesaran (2004) controls the mean value of the CD test.

Second Generation Unit root analysis (CIPS):

CIPS stands for Cross sectionally augumented Im- Pesaran Shin unit root test. Second generation unit root test for panel data is one version of CIPS test (first mentioned in Pesaran) which allows cross sectional dependence. Since Pesaran's unit root test, the conventional IPS test was developed by Pesaran to include cross sectional averages, it can be used for data sets that are experiencing problems in the existence of cross-sectional dependence. Further validation of the work of Pesaran done by various researchers, including (Choi, 2015), makes more sense in as much as this test gives much confident results in such cases.

Autoregressive Distributive Lag Model:

However, let us proceed to evaluate relationships between variables with the unit root analysis. Since the CIPS unit root test did not have consistent order of integration among each of the variables, we opted for the Autoregressive Distributed Lag (ARDL) model as introduced by Pesaran and Shin, which is to also help us investigate the long-run relationship among these different variables in one shot. In such a scenario, the ARDL model will come in, given that the series of both independent and dependent variables will be lagged (i.e. they do not matter whether these series are I (0), I (1) or a mixed order). In addition, this model covers the way using some Error Correction Mechanism (ECM).

In ARDL framework, the ECM captures the short run elasticity of a dependent variable in terms of explanatory variables, i.e. how shortly or slowly adjustment from long run equilibrium returns its original position (Hossain, 2011). Although the changes in relationships among variables evolve, the ECM can summarize via appropriate representations of the divergence and convergence from short run dynamics towards long run equilibrium, which can be seen as a useful summary in terms of divergences and convergences of short run dynamics to long run equilibrium. The current study has comprehensive analysis on the understanding of green economy through analyzing the demand and supply side of the economy.

Supply-Side Model

The dimensions of sustainable development were regressed on green economy indicators and other relevant variables using econometric analysis.

$$\ln GDP_{it} = \alpha_{it} + \beta 1 \ln CO2_{it} + \beta 2 \ln REP_{it} + \beta 3 \ln NREP_{it} + \beta 4 \ln Unp_{it} + \beta 5 \ln FDI_{it} + \beta 6 \ln INF_{it} + \epsilon_{it} \quad \text{(Model 1)}$$

where α represents a constant, and the dependent variable Gross Domestic Product per capita

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(current USD$) and the independent variable are CO_2 emissions (kt), Renewable energy Production (Kwh), Non-Renewable energy production (Kwh), Unemployment, total (% of total labor force) (national estimate)), Foreign Direct investment, net inflows (BoP, current US$), Inflation, consumer prices (annual %) represents CO_2, REP, NREP, Unp, FDI, and INF, and β_1, β_2, ….. β_6 are the coefficients of independent variables and ϵ represents the error term.

The empirical form of ECM can be described for (model 1) as follows:

$$\Delta \ln GDPit = \alpha + \beta 1 \Delta \ln CO2it + \beta 2 \Delta \ln REPit + \beta 3 \Delta \ln NREPit + \cdots + \lambda ECTit - 1 + \epsilon it$$

In this equation, $\Delta GDPit$ represents the short-term change in GDP per capita, current. ΔCO_2it captures the short-term effect of changes in CO_2 emissions on GDP per capita. $\Delta REPit$ Energy Production and Δ NREPit, represent the short-term effects of changes in energy production from renewable and non-renewable sources, respectively. Other variables like FDI, inflation, and unemployment would also be included as changes in these variables, capturing their short-term effects on GDP per capita. $ECTit-1$is the error correction term derived from the long-term relationship between GDP per capita and these explanatory variables.

Demand-Side Model:

$$\ln GDP_{it} = \alpha_{it} + \beta 1 \ln REC_{it} + \beta 2 \ln NREC_{it} + \beta 3 \ln Unp_{it} + \beta 4 \ln FDI_{it} + \beta 5 \ln INF_{it} + \epsilon_{it} \quad \text{…….. (Model 2)}$$

where α represents constant, the dependent variable Gross Domestic Product per capita (current USD$) and the independent variable are Renewable energy consumption (% of total final energy consumption) Energy use (kg of oil equivalent per capita), Unemployment, total (% of total labor force) (national estimate)), Foreign Direct investment, net inflows (BoP, current US$), Inflation, consumer prices (annual %), represents REC, NREC, Unp, FDI, and INF and β_1, β_2, …..β_5 are the coefficients of independent variables and ϵ represents the error term.

The empirical form of ECM can be described for (model 2) as follows:

$$\ln GDPit = \alpha + \beta 1 \Delta \ln RECit + \beta 2 \Delta \ln NRECit + \cdots + \lambda ECTit - 1 + \epsilon it$$

In this equation, $\Delta \ln GDPit$ represents the change in GDP per capita, capturing short-run fluctuations in economic growth. $\Delta \ln RECit$ shows Renewable Energy Consumption and $\Delta \ln NRECit$ indicate Non-Renewable Energy Consumption represent the changes in consumption of renewable and non-renewable energy, respectively, showing their short-run effects on economic performance. $\lambda ECTit-1$is the error correction term, which captures the speed of adjustment back to long-term equilibrium following any short-run disequilibrium. α is the constant term, and ϵ_{it} is the error term.

Westerlund Cointegration Test:

To further investigate the long run relationship of GDP with other independent variables (REP, NREP, REC, NREC, CO_2, Unp INF FDI) from a panel of data, the Wester Lund cointegration test was used. As a result, because none are stationary, the first step was to perform a CIPS test over the unit root of all variables. Westerlund (2007) cointegration test was selected because we could handle the possible structural breaks in a panel data. The

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Westerlund test is more robust to structural breaks than traditional cointegration tests, namely the Westerlund test offers more consistent results with datasets displaying boundary damage.

$$\Delta GDP_{it} = \alpha_i + \delta_i t + \lambda_i GDP_{i(t-1)} + \sum_{j=1}^{p} \gamma_{ij} \Delta GDP_{i(t-j)} + \beta_1 \Delta CO2_{it} + \beta_2 \Delta REP_{it} + \beta_3 \Delta NREP_{it} + \beta_4 \Delta Unp_{it} + \beta_5 \Delta INF_{it} + \beta_6 \Delta FDI_{it} + \epsilon_{it}$$

where Δ denotes the first difference operator. GDP_{it} is the GDP for country i at time t. α_i is the individual-specific intercept. δit captures the deterministic trend component. λ_i is the error correction term coefficient. ϵ is the error term. P is the lag length.

$$\Delta GDP_{it} = \alpha_i + \delta_i t + \lambda_i GDP_{i(t-1)} + \sum_{j=1}^{p} \gamma_{ij} \Delta GDP_{i(t-j)} + \beta_1 \Delta REC_{it} + \beta_2 \Delta NREC_{it} + \beta_3 \Delta Unp_{it} + \beta_4 \Delta INF_{it} + \beta_5 \Delta FDI_{it} + \epsilon_{it}$$

where Δ denotes the first difference operator. GDP is the GDP for country i at time t. αi is the individual-specific intercept. δit captures the deterministic trend component. λi is the error correction term coefficient. ϵ is the error term. P is the lag length.

RESULTS AND INTERPRETATION

The investigation initiated with cross-sectional dependency testing produced substantial proof of inter-sectional dependency through multiple tests including the Pesaran CD as well as Friedman's test along with the Frees CD test.

Table 2: Results of Cross – Sectional Dependance Test

Cross Sectional Dependency Tests:		
CD tests	**Test-stat**	**Prob**
Pesaran CD	25.323	0.0000***
Friedman's test	234.309	0.0000***
Frees CD test	6.420	0.0000***

And ** show the significance level at 1% and 5%, respectively.

Three cross-sectional dependency tests - Pesaran CD, Friedman and Frees CD returned statistics of 25.323, 234.309 and 6.420 respectively as their results showed 0.0000 p-values. Evidence from multiple tests shows that countries share unmeasurable structural elements which produce variations between them so traditional panel estimation methods would be inappropriate for this dataset (Pesaran 2004; Frees 1995).

The Pesaran CD test results in a statistic value of 25.323, which leads to the rejection of the null hypothesis since the p-value falls under 0.05, thus establishing that cross-sectional units display dependent residuals. The results of Friedman's test validate cross-sectional dependence among panel units because it demonstrates a high statistic value of 234.309 and an extremely small p-value of 0.0000 (Friedman, 1937). The Frees CD test supports the existence of cross-sectional dependence through its statistic value of 6.420 and p-value equal to 0.0000 (Frees, 1995).

Test results from every statistical analysis confirm the rejection of cross-sectional

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independence at a 5% significance level thus indicating that observations in the panel data display relationship among them rather than independence. When investigating dependent data, the analysis requires proper econometric methods which include Driscoll-Kraay standard errors and spatial econometric models. Available data analysis methods for panel datasets strongly depend on the presence of cross-sectional dependence because this phenomenon reveals consistent factors which affect multiple units throughout a single period of time. Inadequate treatment of this behavior generates substandard estimator performance which produces desynchronized standard errors and incorrect analysis results (Pesaran, 2015).

Table 3 presents the results of second-generation unit root test. The CIPS unit root tests reveal that the initial values of most dataset variables lack stationarity until their variables become stationary through first differencing. The CIPS statistics show all GDP per capita and CO_2 emissions and variety of energy indicators remain non-stationary at their original positions because the critical values are not exceeded. The CIPS statistics for these variables achieve significant levels of 1% and 5% and 10% after first difference, which proves they are I (1). These findings serve as important information because they help us select either different or cointegration tests to address data non-stationarity following Pesaran (2007).

Table 4.3 Results of CIPS Unit Root Test

Case 1: Unit Root Test at Level		**Case 2: Unit Root Test at First Difference**	
Variables	**CIPS-Stats**	**Variables**	**CIPS-Stats**
GDP per capita current	-1.496	GDP per capita current	-3.362
CO_2 emissions	-0.789	CO_2 emissions	-3.484
Electricity production from renewable sources	-0.654	Electricity production from renewable sources	-3.222
Electricity production from oil, gas and coal sources	-0.472	Electricity production from oil, gas and coal sources	-4.011
Energy use	-1.103	Energy use	-4.469
Renewable energy consumption	-0.139	Renewable energy consumption	-3.404
Unemployment	-2.766	Unemployment	
Foreign direct investment	-3.007	Foreign direct investment	
Inflation	-2.998	Inflation	
Critical Values:		**Critical Values:**	
1%	**-2.3**	**1%**	**-2.3**
5%	**-2.16**	**5%**	**-2.16**
10%	**-2.08**	**10%**	**-2.08**

Table 3 provides evidence that all variables in the first-difference exercise pass the CIPS statistics test at a 1% significance level. The CIPS test statistics indicate that GDP per capita (-3.362), CO_2 emissions (-3.484) along with renewable electricity production from non-solar and non-wind sources (-4.011) have first integrating order (I (1)). The normal

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pattern exists for macroeconomic time series data because GDP and energy variables show non-stationarity in levels until we implement differencing which makes them stationary according to Pesaran (2007).

The variables have been proven to be I (1) properties which are regular characteristics of time-series data in both standalone and panel data approaches (Pesaran, 2007; Levin et al., 2002). The analyzed variables are appropriate for mean econometric analysis through cointegration or error correction modeling.

The long-run regression results of ARDL:

Model 1:

This analysis demonstrates multiple essential relationships between CO_2 emissions and energy production together with foreign direct investment and inflation alongside GDP growth rate. A five percent rise in CO_2 emissions leads to approximately 0.102% expansion of GDP based on the estimated value at 0.1019554 ($p = 0.009$). Positive statistical connections point to economic activities, which produce emissions when emission levels are high. Apergis and Payne (2010) discovered that CO_2 emissions maintain a positive connection with GDP growth at both a short-run and long run scale where industrial production enhances the economy strongly.

Renewable energy production shows no significant impact on GDP in the long run judging from its coefficient of 0.0172689 ($p = 0.384$). The positive relationship between renewable energy and economic growth found by research remains insignificant following statistical testing for significance. This result matches Menegaki (2011) who demonstrated that renewable energy exhibits minimal or no significant influence on economic expansion because of operational weaknesses or because renewable technology developments are new.

A 5% increase in non-renewable energy production leads to a 0.165% reduction in long-term GDP according to the negative coefficient of -0.1648122 ($p = 0.001$). The research by Parikh et al. and Al-Mulali & Ozturk (2016) confirms that negative effects from non-renewable energy sources cause long-term economic damage which is supported by the negative coefficient of -0.1648122 ($p = 0.001$). Results indicate that unemployment shows a brief relationship with GDP through its coefficient value of -0.0614713 ($p < 0.111$). The relationship between unemployment and GDP remains complex according to Blanchard and Wolfers (2000) because the negative coefficient shows that unemployment should not have significant lasting effects on GDP. The results show FDI has a coefficient value of 0.3725978, which holds statistical significance at 5% ($p < 0.0001$) and means a 0.373% GDP increase results from a 1% rise in FDI. The robust positive link between FDI demonstrates its fundamental role in boosting economic growth because FDI introduces capital and technological expertise and managerial expertise to developing economies according to Borensztein, De Gregorio, and Lee (1998).

When inflation rises by 1%, GDP shows a corresponding 0.045% reduction according to the model. Higher inflation rates create adverse effects on long-term economic growth according to the significant negative coefficient value. Research by Fischer (1993) supports findings that show moderate to high inflation negatively alters economic growth because it produces uncertainties that reduce funding investments.

Table 4: Results of ARDL Model in Long-Run for Supply side (Model 1) and Demand side (Model 2)

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Variables	Coefficient	Std.error	z-statistics	p-value
Model 1:				
D.lnGDP				
$lnCO_2$	.1019554	.0390952	2.61	0.009
LnREP	.0172689	.0198371	0.87	0.384
LnNREP	-.1648122	.0514229	-3.21	0.001
LnUnp	-.0614713	.0385753	-1.59	0.111
LnFDI	.3725978	.0234596	15.88	0.0000**
LnINF	-.044866	.0181895	-2.47	0.014
Variables	**Coefficient**	**Std.error**	**z-statistics**	**p-value**
Model 2:				
D.lnGDP				
LnREC	-.5586071	.1242201	-4.50	0.0000**
LnNREC	.028404	.091495	0.31	0.756
LnUnp	-.1075379	.024158	-4.45	0.0000**
LnFDI	.3104397	.0202906	15.30	0.0000**
LnINF	-.0566495	.0153408	-3.69	0.0000**

And ** show the significance level at 5%, respectively.

Model 2:

The study demonstrates multiple important connections that exist between energy use and joblessness, along with foreign direct investment, and inflation rates, and national economic growth. Renewable energy consumption presents a negative long-term effect on GDP at a 5% significance level ($p < 0.0001$) with a coefficient value of -0.5586071. Relevant research data shows that rising renewable energy use may be linked to negative effects that accompany the renewable energy transition. The research conducted by Sadorsky (2009) demonstrated different results because he found renewable energy consumption led to economic growth in specific countries.

The non-statistically significant coefficient value of 0.028404 indicates that non-renewable energy consumption fails to affect GDP in the long-term ($p = 0.756$). Environmental costs along with decreased returns in fossil fuel use explain this significant positive yet irrelevant outcome, which matches patterns found by Ozturk and Acaravci (2010) regarding the waning impact of non-renewable energy on economic growth. Unemployment shows a significant level of 5% with a value of -0.1075379 ($p < 0.0001$). Analysis shows that any 1% unemployment rise leads to a 0.108% GDP reduction thus verifying the negative link between long-term economic growth and unemployment rates. The results validate Okun's law by demonstrating how changes in employment levels create corresponding changes in economic production (Okun, 1963).

The FDI variable exhibits a coefficient value of 0.3104397, which demonstrates strong statistical significance at 5% ($p < 0.0001$) and implies that FDI growth of 1% generates a 0.310% increase in GDP. The results strengthen previous findings of FDI as the key driver for economic development in developing nations (Borensztein et al., 1998).

The last coefficient relates to inflation with a value of -0.0566495 and reaches significance at $p < 0.0001$. A one percent increase in inflation level triggers a 0.057 percent reduction in GDP, which proves the negative relationship between inflation and economic growth. The

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results agree with studies conducted before Fischer (1993) which showed how inflation negatively affects economic performance. The analysis demonstrates that FDI functions as a favorable force for increasing GDP yet inflation manifests as an economic down-factor. Energy variables demonstrate inconsistent effects on the economy, which depend on the renewable or non-renewable nature of energy sources and production or consumption patterns.

4.3 The short-run regression results of ARDL:

Model 1:

The Error Correction Term (ECT) has a significant relationship at the 5% level with a coefficient value of -0.11881 (p = 0.023) which shows that about 11.88% of GDP disequilibrium automatically corrects during each period at a moderate speed. The negative significance of ECT at the 5% level indicates a slow rate of long-run equilibrium restoration according to Banerjee, Dolado, and Mestre (1998) whose research demonstrated that error correction maintains variable relationships in ARDL models.

The current data reveals CO_2 emissions exhibit a small positive correlation to GDP, which proves not statistically meaningful since the coefficient value stands at 0.0012303 (p = 0.990) in the short run. The economic impacts from environmental degradation become visible later. The coefficient value -0.0351106 (p = 0.783) indicates that renewable energy production (D1. lnREP) has no significantly negative correlation with GDP during the short run period. Menegaki (2011) discovered in his research that renewable energy brings stronger growth.

Table 5: Results of ARDL Model in Short-Run for Supply side (Model 1) and Demand side (Model 2)

Variables	**Coefficient**	**Std. error**	**z-statistics**	**p-value**
Model 1:				
D. lnGDP				
ECT	-.11881	.0523146	-2.27	0.023
D1. $lnCO_2$	.0012303	.0952758	. 0.01	0.990
D1. lnREP	-.0351106	.1272152	-0.28	0.783
D1. lnNREP	-11.6916	11.24624	-1.04	0.299
D1. lnUnp	-.0440675	.1067475	-0.41	0.680
D1. lnFDI	.0033796	.0111407	0.30	0.762
D1. lnINF	-.0029807	.0125307	-0.24	0.812
_cons	.0101817	.0674473	0.15	0.880
Variables	**Coefficient**	**Std. error**	**z-statistics**	**p-value**
Model 2:				
D.lnGDP				
ECT	-.1070939	0443722	-2.41	0.016
D1. lnREC	-.111408	.1474885	-0.76	0.450
D1. lnNREC	.1457825	.0758256	1.92	0.055
D1. lnUnp	-.0625893	.0632826	-0.99	0.323
D1. lnFDI	-.00015	.0132029	-0.01	0.991
D1. lnINF	-.0006575	.0092913	-0.07	0.944
_cons	.085281	.0237165	3.60	0.0000***

And ** show the significance level at 1% and 5%, respectively.

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impact on economies when studied through a long-term analysis. The coefficient -11.6916 indicates non-renewable energy production (D1. lnNREP) hurts GDP yet statistical significance remains at p = 0.299, thus failing to prove immediate variations in non-renewable energy consumption influence GDP. The economic advantages of non-renewable energy generate environmental and social costs that exceed the initial benefits per Ozturk and Acaravci (2010) research. The results show unemployment (D1. lnUnp) generates a -0.0440675 effect on GDP (p = 0.680) yet this finding is not statistically important to confirm the relationship. The findings align with Blanchard and Blanchard and Katz, 1992 who observed that unemployment produces ambiguous effects on GDP in the first few years because of several economic variables.

The effect of direct foreign investment (D1. lnFDI) on GDP in the short term is minimal based on its positive coefficient value (0.0033796) but shows no statistical significance (p = 0.762). Research indicates that FDI benefits need time to develop, which matches findings about FDI, and economic performance delays reported by De Mello (1997). Research findings demonstrate that inflation (D1. lnINF) delivers a non-statistically meaningful negative impact on GDP through its coefficient of -0.0029807 (p = 0.812). Bruno and Easterly (1998) established that inflation creates more substantial economic growth impact through its long-term effects rather than short-term effects, which this research supports. The outcomes reveal diverse connections between energy consumption, together with additional economic factors to GDP, while demonstrating the complex nature of these relationships between different time horizons.

Model 2:

Results from the Error Correction Term show a significant coefficient of -0.1070939 (p = 0.016) which indicates an approximately 10.71% self-correction of any long-run equilibrium deviation in each period. The established coefficient of -0.1070939 (p = 0.016) supports Banerjee et al. (1998) by demonstrating that the Error Correction Term aids disequilibrium adjustment at a steady rate. The analysis between renewable energy usage (D1. lnREC) and GDP shows no significant relationship (p = 0.450) with a coefficient of -0.111408. This finding indicates that brief renewable energy consumption patterns do not substantively affect GDP even though Sadorsky (2009) pointed out high costs and inefficiencies of renewable technology adoption. The analysis reveals that short-term non-renewable energy consumption (D1. lnNREC) leads to GDP increase with a coefficient of 0.1457825 at a marginal significance level (p = 0.055) although Stern (2011) notes that environmental limits restrict non-renewable use, but it supports short-term economic advancement. Unemployment variable (D1. lnUnp) shows a net negative impact on GDP based on the coefficient value of -0.0625893 (p = 0.323). Foreign direct investment (D1. lnFDI) yields a minimal coefficient of -0.00015 while maintaining an insignificant p-value at 0.991, thus highlighting minimal short-term effects on GDP according to De Mello's (1997) view of FDI long-term benefits. The inflation variable (D1. lnINF) demonstrates an insignificant relationship to economic growth through its coefficient of -0.0006575 (p = 0.944) following Bruno and Easterly (1998). The analysis indicates that major economic variables such as CO_2 emissions and renewable and non-renewable energy production along with unemployment and FDI and inflation do not substantially affect GDP immediately, yet the equilibrium error correction term shows how the system reaches its stable equilibrium level after short-lived disturbances, thereby indicating strong long-term effects.

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Westerlund Cointegration Test:

Model 1:

Table 6 presents the p- values of Gt and Ga and Pt and nearly zero. This result validates earlier findings from Westerlund et al. (2007) and Westerlund (2012) about the Gt and Pt tests' success in detecting cointegration in small sample sizes with cross-sectional dependence. The cointegration analysis confirmed by the Augmented Dickey-Fuller test which results in the rejection of non-cointegration hypothesis (see Tables 1 and 2). The results match findings presented by Pedroni (2004) together with Banerjee et al. (2005) who uncovered long-run equilibrium relationships using panel cointegration methods.

Table 6: Results of Westerlund Cointegration Test for Supply side (Model 1) and Demand side (Model 2)

Model 1:			
Statistic	**Value**	**z-value**	**P-value**
Gt	-8.039	-26.927	0.000***
Ga	-23.532	-7.213	0.0000***
Pt	-312.284	-248.312	0.0000***
Pa	-155.833	-87.175	0.0000***
Model 2:			
Statistic	Value	z-value	P-value
Gt	-5.289	-13.161	0.0000***
Ga	0.254	7.934	1.000
Pt	-11.545	-1.319	0.093
Pa	-5.047	2.657	0.996

And ** show the significance level 5%, respectively.

Model 2:

The Gt test confirms the 5% statistical significance (p = 0.000), yet the Ga, Pt, and Pa tests produce useless results with p-values of 1.000, 0.093, and 0.996 respectively which show no solid evidence for cointegration across all tests. This mixed evidence demonstrates that the variables possess potential long-run correlations, but the results lack reliable consistency based on tests for stationarity. Kao (1999) and Maddala and Wu (1999) join the existing literature demonstrating that cointegration tests become sensitive to specific choices as well as test statistic variations.

Model 1 demonstrates a robust long-term connection between its variables, although Model 2 indicates limited cointegration patterns according to Persyn and Westerlund (2008), while examining different models and variables. The selection process of variables for cointegration tests should remain vigilant due to the different characteristics of model variables, according to Persyn and Westerlund (2008).

Conclusion

This research evaluates how the green economy supports sustainable economic advancement across 22 Asian nations during 1990 to 2023 based on econometric analysis, which measures

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CO_2 emission patterns alongside renewable and non-renewable energy consumption and production, as well as FDI flows and inflation rates. The research implements a fixed-effect model to deal with country-specific effects, yet it utilizes the CIPS unit root test proposed by Pesaran for examining cross-sectional dependence in panel data.

The research uses a bias-corrected analytical procedure that performs unit root assessment before applying the Autoregressive Distributed Lag (ARDL) model to establish both long-term and short-term relationships between the examined variables. The error correction model (ECM) facilitates the examination of short-run income elasticity and the adjustment process toward long-run equilibrium. The analysis evaluates long-term relationships between GDP and independent variables through the Westerlund cointegration test that deals with structural breaks in panel data.

Results of the long-run ARDL model present a mixture of findings because CO_2 emissions and non-renewable energy production have negative impacts on GDP, although FDI delivers positive results. Conversely, renewable energy consumption and unemployment display no strong long-run relationships with GDP. The short duration analysis reveals that GDP fluctuations generate minor reaction changes in variables, which include energy prices, unemployment rates, as well as FDI and inflation levels. The values of error correction coefficients in both models show how equilibrium requires time to recover after brief disturbances occur. The Westerlund cointegration test shows diverse results since Model 1 (Supply Side) demonstrates the existence of cointegration but Model 2 (Demand Side) partially rejects the null hypothesis during certain statistical tests. This research demonstrates the complex system of relationships between Asian country economic development and their energy consumption as well as macroeconomic elements.

The research introduces various policy recommendations that support sustainable economic development. Green economic activities need promotion because research indicates positive CO_2 emissions and GDP connection identified in Model 1. Hereby oriented industrial incentives from government agencies create economic growth through environmentally friendly practices, which minimize climate damage from basic manufacturing.

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