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The Impact of Nuclear Energy Consumption on Economic Growth and CO_2 Emissions in Selected Asian Economies

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ABSTRACT

Most countries' economic policies aim towards long-term growth in the economy. The economic growth has an effect on global warming and climate change, which are two of the biggest problems and worries in the world. Because of economic growth and civilization, the amount of carbon dioxide (CO2) and other greenhouse gases (GHG) in the air has gone up. In order to do this, the study used the Dumitrescu and Hurlin (D-H) and Common Correlated Effect Mean Group (CCE-MG) causality tests to look at how nuclear energy affected economic growth in some Asian countries from 1990 to 2017. The results of CCE-MG showed that developing countries in Asia used less renewable energy and nuclear energy than they thought they would. On the other side, the use of non-renewable energy had the negative effect on economic growth. Further, it was observed that the renewable energy had a positive effect on the amount of CO2 released in developing countries. Based on the results, the study suggested that the government and policymakers should focus on renewable energy sources to help them grow while at the same time putting in place environmental rules to protect the environment.

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1. Introduction

In most countries around the world, sustained economic growth over the long term is a top priority for economic policymakers. Conversely, economic expansion may influence two of the most pressing global issues and concerns: climate change and global warming. As a consequence of economic development and civilization, greenhouse gas and carbon dioxide (CO_2) emissions in the atmosphere have risen. In general, there is a great deal of data in the literature on the relationship among energy use, CO_2 emissions, and country's economic output (Ahmad et al., 2016)

How energy use affects the relationship between growth and environmental quality, it is often said that continuing to use fossil fuels is bad for the environment because fossil fuel combustion releases a lot of greenhouse gases into the air. Also, research has shown that switching from dirty energy sources to ones that aren't too bad for the environment is linked to both economic growth and less pollution in the environment (Nathaniel & Iheonu, 2019). So, plans to switch from fossil fuels to renewable energy (RE) over time have become one of the most important goals of global energy policy in the 21st century (Murshed, 2021; Murshed & Alam, 2021).

Several studies have examined the connection between renewable energy usage and GDP, or between energy consumption per GDP and CO_2 emissions, however the findings have varied due to country and methodological variations. Few researchers, such as (Bekhet & Othman, 2018; Bélaïd & Youssef, 2017; Bilgili, Koçak, & Bulut, 2016) discovered a one-way causal relationship between renewable energy (RE) and CO_2.Numerous studies have shown a correlation between GDP, renewable energy, and CO2 emissions. Apergis, Payne, Menyah, and Wolde-Rufael (2010), for example, investigated the energy-growth nexus in nineteen developed and developing economies. The findings show that although NE contributes to emission reduction but renewable energy does not. According to Raza and Shah (2018), GDP is long-term positively linked to CO2 emissions, with a reverse causal relationship between CO_2 emissions and renewable energy consumption among the G7 nations. Granger causation between RE and CO2 emissions was found in the short run for 15 EU member states (Dogan & Seker, 2016) and in the long run for BRICS countries (Dong, Sun, Jiang, & Zeng, 2018).

Globally, nuclear energy (NE) usage has risen by more than 37% in order to maintain and accelerate development (Al-Mulali, 2014). Researchers have been examining the connection among NE, CO2 emissions, and GDP for many years. The study of (Baek & Pride, 2014; Lee, Kim, & Lee, 2017; Ma, Østergaard, Lund, Yang, & Lu, 2014; Xu, Kang, & Yuan, 2018) indicates that using nuclear energy may result in a reduction in discharges. Alam (2013) found unfavorable results for 11 OCED states and a panel of 25 states. Iwata, Okada, and Samreth (2010) shown that the use of NE increases CO2 emissions, while Sarkodie and Adams (2018) demonstrated that the use of NE has a negative effect on carbon discharge. In France, Yoo and Jung (2005) found that NE reduces carbon emissions. NE contributes to environmental pollution. Yoo and Jung (2005) showed unidirectional causation between NE and GDP, as did previous researchers (Wolde-Rufael, 2010). On the other hand, some studies found a relationship between NE consumption and GDP neutrality (Nazlioglu, Lebe, & Kayhan, 2011; Payne & Taylor, 2010).

Asian countries are witnessing a boom in work possibilities, which is causing metropolitan areas in these nations to undergo an anthropogenic shift. This shift is triggered by the increased labour force demand induced by growth in industrial activities. This change in labour force concentration toward cities has spurred an increase in energy consumption, which has resulted in an increase in ambient air pollution. The issue of unsustainable urbanization was highlighted in the (HDR, 2019) when discussing the economic disparity prevalent in these nations, and the problem of growing CO2 emissions was also credited to rising urbanization (Conceiçao, 2019).

Now, these countries are looking into renewable energy sources to meet the rising energy needs of their urban centers while also protecting and improving their environments. In order to achieve energy security and improve environmental quality in Asian nations, the International Energy Agency's most recent report ranked the development and deployment of renewable energy options (Naqvi, Shah, Anwar, & Raza, 2021). Since then, it has recommended setting up proper financialization channels to enable investment in renewable energy generation technologies. Existing financialization channels are more likely to stimulate industrialization and, as a result, environmental destruction; nevertheless, these new financialization channels may aid in the development and deployment of domestic renewable energy systems. South Asian economies were the focus of the Asian Development Bank's study on green energy financing in Asia (Peimani, 2019). From this vantage point, it's evident that the current regulatory structure in Asian countries may pose a challenge to delivering on the SDG 7 targets of providing clean and inexpensive energy solutions. The Objectives of study are to identify the impact of nuclear energy consumption on economic growth and CO_2 emissions in selected Asian Countries, to identify the causal relationship among the selected macroeconomic variables and to suggest suitable policy implications from the results of this study.

2. Review of Literature

Magazzino, Mele, Schneider, and Vallet (2020) investigated the contextual investigation of Switzerland in the connection to discover the connection between financial development and thermal power utilization affirmation from the period 1970–2018. The factors were utilized fare, capital, work thermal power, and GDP. VAR model and relationship were utilized to assess information. The aftereffect of the study is, featured how the impacts of the relinquishment of thermal power can make antagonistic consequences for GDP development in the coming years. Vo, Vo, Ho, and Nguyen (2020) explained the contextual investigation of CPTPP nations in the connection to discover the job of renewable energy, nuclear energy, and options in modifying carbon emissions in the CPTPP Countries period from 1971 to 2014. The factors were utilized, petroleum product-based energy, thermal power, sustainable power, and CO2. The model was utilized (FMOLS) to assess information. The aftereffect of the investigation today is the issue of worldwide warming due to the expansion in CO2 discharges the conceivable arrangement is the utilization of cleaner wellsprings of energy to diminishing CO2. (Nawaz, Hussain, & Hussain, 2021) examined the impact of green financial development on economic growth of Pakistan for the period of 1981 – 2019. The empirical results of ARDL showed that green financial development such as green credit, green securities, green insurance, green investment, and foreign direct investment have a positive impact on the economic growth of Pakistan.

Abbasi, Parveen, Khan, and Kamal (2020) explicated the contextual investigation in the connection to discover energy utilization and Urbanization consequences for carbon dioxide discharge: proof from Asian-8 nations utilizing board information examination the period 1982 to 2017. There is an OLS model that can be utilized. The factors are utilizing carbon dioxide (CO2) emanations, Y is the per capita GDP, EU shows the energy utilization, FD is the monetary turn of events, UR portrays urbanization, and TO is the exchange receptiveness. The aftereffect of the study is, unidirectional causality exists between CO2 outflows and energy utilization, this investigation offers significant approach suggestions for plunging fossil fuel byproducts. Naqvi et al. (2021) investigated the contextual investigation of Pakistan in the connection to discover monetary turn of events, Renewable energy, and biological impression nexus proof of sustainable power climate Kuznets bend from pay bunches information examination from 1990 t0 2017. OLS model was utilized to appraise the information. The factors were utilized sustainable power utilization, genuine monetary development per capita, and monetary advancement with environmental impressions. The after effect of study is the policymakers in dynamic concerning the turn of events and use of sustainable power to stay away from natural harms.

Z. Chen and Zhou (2021) investigated the impact of urbanization on energy intensity, taking a number of factors into consideration, including the fast development of urbanization as well as issues about energy security based on panel data collected from 72 countries between 2000 and 2014. In order to examine the effect of institutional efficiency on the connection between urbanization and energy intensity, a panel threshold model was employed. According to the results, increased urbanization is associated with a rise in the intensity of energy use. According to the findings of the research, when institutional efficiency reaches a certain level, the beneficial impacts of urbanization on energy intensity are reduced by 0.033, reducing their magnitude. In accordance with the results, increasing urbanization is associated with increased energy intensity. According to the research, when institutional efficiency reaches a specific threshold, the beneficial impact of urbanization on energy intensity is decreased by 0.033, which is a small but significant reduction. Finally, the effect of the institutional barrier was substantial only for the fossil energy sector, and not for the renewable energy community, as was previously stated.

From 1978 to 2016, Shen and Lin (2021) estimated the manufacturing structure distortion index of China's provinces and analysed its impact on China's energy intensity. The results showed that the distortion index of China's industrial structure fell dramatically between 1978 and 2016, and that the index was a major factor in determining the energy power of individual provinces. Research and development spending had little effect on China's energy strength, but energy prices, exports, and FDI did. If China wants to reduce energy intensity, the research suggests the country work on eliminating the granular causes of distortions in its industrial structure and developing a process for setting factor prices that is based on market forces. Wang and Wang (2021) developed a panel threshold regression (PTR) model utilizing data from 137 nations or regions from 2002 to 2012 in order to examine the nonlinear influence of population ageing on CO2 emissions. Population ageing was used as a threshold variable, while the industrial structure and urbanization were used as explanatory factors in the PTR model. Carbon emissions were the explained variable in the PTR model. Control factors such as economic growth, trade independence, population size, and financial position were also included in the analysis. In particular, the results show that as the population ages, the relationship between industrial structure and carbon emissions in the high-income, upper-middle-income, and low-income classes becomes positive, negative, and "U"-shaped backwards. The correlations between urbanization and carbon emissions form an inverted "U" as the population ages, whereas the correlations between urbanization and carbon emissions form nonlinear and positive patterns in the communities with higher incomes (upper middle class, lower middle class, and lower-middle class).

Bashir, Susetyo, Suhel, and Azwardi (2021) looked into how urbanization, economic growth, energy use, and CO2 emissions in Indonesia are related. The World Development Indicators database, which had information on a wide range of development indicators from 1985 to 2017, was used to find these results. The study used the vector error correction model to fix mistakes in the data. It was based on the Granger causality test. Also, the real-world results showed that urbanization and energy use may contribute to CO2 pollution in the near future. They also showed that urbanization may contribute to energy use. Other results included long-term links between energy use, economic growth, and CO2 emissions, as well as a link between urbanization, economic growth, and CO2 emissions, and a link between energy use and CO2 emissions. Several studies, like one in Indonesia that looked at how economic growth affects CO2 emissions, showed that the EKC theory was correct. After thinking about these results, researchers concluded that regulations are needed to counteract the bad effects of urbanization through more knowledge and more energy use in order to keep the quality of the environment.

It is summarized that none of the previous study examined the impact of nuclear energy consumption on economic growth in these selected countries of Asia with perspective of developing and developed nations. Though, several studies had estimated this effect through aggregate energy consumption as well as renewable energy consumption. Furthermore, it is also noted that previous studies used first generation techniques for their analysis but in our study, we will use second generation techniques for the estimation of desired objectives.

3. Material and Methods

The current analysis examined yearly data from 1990 to 2017 for 12 Asian nations. These nations were divided into 12 developing countries (Thailand, Iraq, Tajikistan, the Philippines, Pakistan, China, Indonesia, India, Georgia, Armenia, Azerbaijan, and Bangladesh). The sample nations were chosen based on the availability of relevant data for the study's variables. All variables' data is gathered from World Development Indicators (WDI). Table 1 contains a breakdown of the variables.

Table 1: Description of variables

Indicator	Abbreviation	Measurement	Source
Economic growth	GDP	GDP growth (annual %)	WDI
Carbon emissions	CO_2	emissions (kt)	WDI
Renewable energy consumption	RE	(% of total energy use)	WDI
Nuclear energy consumption	NE	(% of total final energy consumption)	WDI
Non-renewable energy consumption	NRE	kg of oil equivalent per capita	WDI

3.1. Model specification

Two models are used in this study to do empirical analysis and reach the goals of the study.

3.1.1. Econometric model for economic growth

First, the study uses the theoretical framework to build an econometric model-1 for growth. This model is used to measure the effects of independent series on the dependent variable. The equation for Model-1 can be written as follows:

$$GDP = f(RE, NE, NR) \qquad (1)$$

GDP is a function of nuclear energy (NE), renewable energy consumption (RE), and non-renewable energy consumption (NR), according to Eq. (1). As seen below, Eq. (1) is expressed in panel data form:

$$GDP_{it} = \gamma_0 + \gamma_1 RE_{it} + \gamma_2 NE_{it} + \gamma_3 NR_{it} + \mu_{it} \quad (2)$$

The preceding model is represented in log-linear form as follows:

$$LGDP_{it} = \gamma_0 + \gamma_1 LRE_{it} + \gamma_2 LNE_{it} + \gamma_3 LNR_{it} + \mu_{it} \quad (3)$$

Here, $\gamma_0$is intercept andμ_{it} indicate an error term and γ_1, γ_2, $\gamma_3$are parameter estimates of relevant explanatory variables.

3.1.2. Econometric model for CO_2 Emissions

The panel model 2 of the current investigation involves carbon emissions. Another aspect of our research is the effect of NE, RE, and NR consumption on CO2. Model-2's equation may be expressed as follows:

$$CO2 = f(RE, NE, NR) \quad (4)$$

According to Eq. (4), CO_2 is a function of nuclear energy (NE), renewable energy consumption (RE), and non-renewable energy consumption (NR). As seen below, Eq. (5) is expressed in panel data form:

$$CO2_{it} = \gamma_0 + \gamma_1 RE_{it} + \gamma_2 NE_{it} + \gamma_3 NR_{it} + \mu_{it} \quad (5)$$

Eq. (5)'s log transformation is as follows:

$$LCO2_{it} = \gamma_0 + \gamma_1 LRE_{it} + \gamma_2 LNE_{it} + \gamma_3 LNR_{it} + \mu_{it} \quad (6)$$

Here, $\gamma_0$is intercept andμ_{it} indicate an error term and γ_1, γ_2, $\gamma_3$are parameter estimates of relevThe CSD tests assist in overcoming panel data problems and ensuring the estimators' robustness and consistency. (Nathaniel et al., 2021). For this concern we have used two CSD test which are developed by (Pesaran, 2004) and (Friedman, 1937) and mathematical equations (7 & 8) of these CSD tests are given below;

$$\text{CSD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) N(0,1) \quad (7)$$

$$\text{FRI} = (j\text{-}1)\left[\frac{2}{N}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\gamma ij + 1\right]\chi 2\ (j\text{-}1) \quad (8)$$

Where, $\hat{\rho}_{ij}$, T, and N are the pair-wise cross-sectional correlation coefficients, the sample size and size of panel, respectively. If our data support CSD, we will use econometric approaches to solve CSD concerns. Because we wish to examine a dataset where T > N, we're concerned about the outcome of the Breusch-Pagan LM tests. The test statistics of CADF is expressed in Equation (9).

$$\Delta X_{it} = \Phi_i + \delta_i X_{i,t-1} + \gamma_i \bar{X}_{t-1} + \Psi_i \Delta \bar{X}_t + \mu_{it} \quad (9)$$

Test's calculating process is described in equation (10).

$$\Delta Y_{it} = \delta'_i d_t + \eta_i\left(Y_{i,t-1} - \beta'_i x_{i,t-1}\right) + \sum_{j=1}^{p_i}\eta_{ij}\Delta y_{i,t-j} + \sum_{j=0}^{p_i}\gamma_{ij}\Delta x_{i,t-j} + \mu_{it} \quad (10)$$

$$\Delta Y_{it} = \delta'_i d_t + \eta_i\left(Y_{i,t-1} - \beta'_i x_{i,t-1}\right) + \sum_{j=1}^{p_i}\eta_{ij}\Delta y_{i,t-j} + \sum_{j=0}^{p_i}\gamma_{ij}\Delta x_{i,t-j} + \mu_{it} \quad (10)$$

In equation (11), the constant term $d_t = 1$ constant trend. Similarly, (0) indicates that there is no constant trend, while (1, t) indicates that there is both a constant and a trend. The adjustment speed is $=\eta_i$ in this case. This technique takes into account the potential for cross-country dependence among variables, resulting in a stable solution (Pesaran, 2006). The D-H panel causality can be expressed as in Equation (11):

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K}\theta_{ik}\, y_{i,t-k} = \sum_{k=1}^{K}\varphi_{ik}\, x_{i,t-k} + \varepsilon_{it} \quad (11)$$

Where $y_{i,t}$ and $X_{i,t}$ are two stationarity variables at the period and K represents the lag order which is further presumed to be same for selected panel, but parameters θi and ψi differentiate.

4. Results and Discussion

This section reports the estimated findings for developing countries including results of descriptive and correlation analysis, CSD tests, unit root tests, Westerlund cointegration test, CCE-MG and D-H granger causality test for model 1 and 2. In this regard, 4.1.1 represents the results of descriptive and correlation analysis, 4.1.2 and 4.1.3 reported the results of CSD tests, unit root, cointegration, CCE-MG and granger causality test for model 1 and 2, respectively.

4.1. Results of Descriptive and Correlation Analysis for Developing Countries

In this sub-section, results of descriptive statistics and correlation analysis for developing countries are reported. Table 2 displays the variables' descriptive statistics for developing countries. From the data, the value of LCO2 ranges from 2.890647 to 7.012497 with a mean and median value of 4.831727 and 4.868714, respectively. While, LGDP ranges from -0.920301 to 1.806500 with a mean and median value of 0.734726 and 0.767574, respectively. The data on LNE vary from -5.554293 to 1.744893, with median and mean values of 0.279163 and -0.014593, respectively. On the other hand, the value of LNR ranges from 2.075176 to 3.926265 with a mean and median value of 2.885342 and 2.864749, respectively. Similarly, the data on LRE ranges from -2.228255 to 1.978271 with mean and median value of 1.092062 and 1.523023, respectively. Further, the outcomes demonstrate that the mean, median, maximum and minimum values of LCO2 are higher than other variables of study. It is also evident from the descriptive statistics that all the variables are platykurtic except LCO2 as its respective value of kurtosis is less than The LGDP, LNE and LRE are negatively skewed whereas, LCO2 and LNR are positively skewed. In addition, all the variables have significant probabilities with positive Jarque-Bera values.

Table 2: Descriptive Results

	LCO2	LGDP	LNE	LNR	LRE
Mean	4.831727	0.734726	-0.014593	2.885342	1.092062
Median	4.868714	0.767574	0.279163	2.864749	1.523023
Maximum	7.012497	1.806500	1.744893	3.926265	1.978271
Minimum	2.890647	-0.920301	-5.554293	2.075176	-2.228255
Std. Dev.	0.966238	0.367732	1.465237	0.373956	1.040703
Skewness	0.147603	-0.872176	-2.167593	0.467928	-1.971756
Kurtosis	2.322902	6.207622	7.855582	3.190984	6.107262
Jarque-Bera	8.866119	216.6386	688.5209	14.82489	409.6034
Probability	0.011878	0.000000	0.000000	0.000604	0.000000

Table 3 displays the correlation coefficients of the variables understudy for developing countries. The correlation results denote strong correlations between the variables. However, the correlation coefficient matrix shows that LCO2 has a positive association with LGDP and LNR but at the same time it has a negative connection with LNE and LRE. The relationship of LNE and LRE with LGDP is positive except LNR, implying that nuclear energy and renewable energy consumption contributes to economic growth, while non-renewable energy consumption reduces the economic growth in these developing countries of Asia. Moreover, LNR has negative correlation with LNE while, LRE has positive correlation with nuclear energy. Lastly, LRE has positive correlation with LNR in these economies.

Table 3: Correlation results

	LCO2	LGDP	LNE	LNR	LRE
LCO2	1	0.0154746	-0.37202846	0.3634842	-0.21202461
LGDP	0.01547463	1	0.1748761	-0.01353098	0.0288322
LNE	-0.3720284	0.174876	1	-0.56733242	0.8067744
LNR	0.36348428	-0.013530	-0.56733242	1	-0.8056638
LRE	-0.21202461	0.0288322	0.8067744	0.8056638	1

4.2. Results of model 1 for developing countries

This sub-section displays the results of CSD tests, Unit root tests, Westerlund cointegration test, CCE-MG and D-H granger causality test for model 1 & 2 in context of developing countries. Table 4 shows the results of CSD tests for model 1 & 2 with regard to panel of developing countries. For CSD, the Pesaran, Friedman, and frees tests were employed. The three calculated test statistics show that the null assumption may be rejected, showing that residuals are reliant on the presence of cross-section, according to the findings. The interconnectedness of most nations in the globalized world is one of the driving forces behind the CSD. Any shock in one of the sample countries would have an impact on the other sample countries. As a result of the overspill effects, the variables are cross-sectionally dependent. These results give us an indication to use second generation unit root tests which accounted the problem of CSD in the panel data.

Table 4: Cross-sectional dependency results for Model 1

CSD tests	T statistics	P values
Pesaran	2.824***	0.0047
Friedman	59.492***	0.0000
Frees	0.536***	
Cross-sectional dependency results for Model 2		
CSD tests	**T statistics**	**P values**
Pesaran	6.440***	0.0000
Friedman	68.606***	0.0000
Frees	4.640***	

Notes: *** = (≤1%) level of significance.

This research employs two robust root unit tests (i.e., CADF and CIPS) to address all of the previously described problems. The results of the both unit root tests are presented in Table 4.4. Except for LGDP and CO2, the CIPS test results indicate that all variables are non-stationary at the level. However, after taking their first difference, the variables become stationary. Furthermore, the results of CADF test show that the variables LGDP and LCO2 are stationary at both level and first difference with 1% significance level. Moreover, the remaining variables are stationary at first difference, as shown in Table 5.

Table 5: Results of CIPS and CADF unit root tests

CIPS				
Variable	**At level**		**At 1st difference**	
	T-statistics		**T-statistics**	
LGDP	-4.158***		-6.013***	
LCO2	-2.224*		-4.340***	
LRE	-1.386		-4.551***	
LNE	-1.899		-5.012***	
LNR	-1.722		-4.502***	
CADF				
Variable	**At level**		**At 1st difference**	
	T-statistics	**Prob.**	**T-statistics**	**Prob.**
LGDP	-2.925	0.000***	-4.830	0.000***
LCO2	-2.634	0.001***	-3.408	0.000***
LRE	-1.992	0.214	-3.199	0.000***
LNE	-1.829	0.416	-4.441	0.000***
LNR	-2.663	0.001***	-3.494	0.000***

Notes: * = (≤10%) and *** = (≤1%) level of significance

4.3 Westerlund cointegration results of model 1 & 2 for developing countries

Subsequently, stationary results of unit root tests allow us to conduct the Westerlund cointegration test. Table 6 reports the Westerlund panel cointegration results of model 1 for developing countries. Gt, Ga, Pt, and Pa are the four major parameters that influence the outcome. The results demonstrate that the Pt and Pt for model 1 reject the original hypothesis at the 1% and 10% significance level, indicating that the selected variables do indeed have long-term cointegration. As a result, the long-run relationship among the coefficients may now be estimated in the following phase.

For Model 2 the results demonstrate that the Gt, Ga, Pt for model 1 reject the original hypothesis at the 1% and 5% significance level, indicating that the selected variables do indeed have long-term cointegration. As a result, the long-run relationship among the coefficients may now be estimated for model 2.

Table 6: Westerlund Cointegration results for Model 1

	Model 1:	**$LGDP_{i,t}$= f($LRE_{i,t}$, $LNE_{i,t}$, $LNR_{i,t}$)**		
Statistic	**Value**	**Z-value**	**P-value**	**Robust P-value**
Gt	-2.339	1.570	0.942	0.380
Ga	-3.707	5.506	1.000	0.990
Pt	-6.704	2.670	0.996	0.000***
Pa	-4.198	3.915	1.000	0.050*
		Westerlund Cointegration results for Model 2		
	Model 2:	**$LCO2_{i,t}$= f($LRE_{i,t}$, $LNE_{i,t}$, $LNR_{i,t}$)**		
Statistic	**Value**	**Z-value**	**P-value**	**Robust P-value**
Gt	-3.307	-2.588	0.005	0.020**
Ga	-6.966	3.986	1.000	0.030**
Pt	-8.185	1.097	0.004	0.000***
Pa	-5.219	3.414	1.000	0.440

Notes: ∗= (≤10%) ∗∗∗ = (≤1%) level of significance.

4.4 CCE-MG results of model 1 & 2 for developing countries

After finishing the cointegration analysis, we used the CCE-MG technique to determine the long-run elasticities of model 1. Table 7 displays the results of the CCE-MG estimator. The long run coefficient value of nuclear energy consumption (LNE) is significantly negative in model 1, suggesting that the rise in nuclear energy lowers the economic growth in the long run by -.055% for developing countries. This negative effect of nuclear energy consumption on economic growth in developing countries indicates that the share of nuclear energy consumption is less than the other energy sources in developing countries. As, the nuclear energy consumption could not fulfill the energy demand of the developing countries, so this effect goes to the negative in the economies. This long-run impact of nuclear energy consumption on economic growth is supported by the study by Azam, Rafiq, Shafique, Zhang, and Yuan (2021) for India, Russia and Germany.

Next, renewable energy consumption has also a negative and statistically significant influence on economic growth at a 1% level. This negative sign of renewable energy on economic growth implies that renewable energy consumption reduces the economic growth in developing countries of Asia. The coefficient of renewable energy consumption is equal to 1.844, meaning that a 1% increase in renewable energy consumption may reduce an economic growth by 1.844%. This long-run impact of renewable energy consumption on economic growth is supported by the study by (Azam et al., 2021) for Russia and UK, but contradicts to the findings for developing countries.

Further, the coefficient value of non-renewable energy consumption has opposite results than nuclear energy consumption and renewable energy consumption in developing countries. The results of CCE-MG estimator show that non-renewable energy consumption has positive and significant association with economic growth in developing countries. The positive sign indicates that developing countries are fulfilling their energy requirement with major share of non-renewable energy.

As, developing countries have not much advanced technology that's why these economies accelerate their sectors with non-renewable energy. In this regard, non-renewable energy consumptions positively contribute to economic growth in these nations. Additionally, the coefficient of non-renewable energy consumption is equal to 0.828, meaning that a 1% increase in renewable energy consumption may increase an economic growth by 0.828%. This positive effect of non-renewable energy consumption on economic growth is in line with the findings Shahbaz, Raghutla, Chittedi, Jiao, and Vo (2020) for renewable energy country attractive index.

Model 2 displays the results of the CCE-MG estimator. The long run coefficient value of nuclear energy consumption (LNE) is significantly negative in model 2, suggesting that the rise in nuclear energy lowers the carbon emissions in the long run by -.0148% for developing countries. This negative effect of nuclear energy consumption on CO2 emissions in developing countries indicates that as, the nuclear energy consumption is a part of renewable and clean energy, so this effect goes to the negative in these developing economies of Asia. The result is in line with the finding of Azam et al. (2021) for USA, Canada, India, Japan, UK and China.

Interestingly, renewable energy consumption has a positive and statistically significant influence on CO2 emissions at a 1% level. This positive sign supports the fact that renewable energy consumption increases the CO2 emissions in developing countries of Asia. This value is positive might be due to lower share of renewable energy in total energy consumption. The fact is that developing countries mainly depends on non-renewable energy which eliminates the effect of renewable energy on CO2 emissions. The coefficient of renewable energy consumption is equal to 1.214, meaning that a 1% increase in renewable energy consumption may reduce an economic growth by 1.214%. The result is in line with the finding of Azam et al. (2021) for Russia.

Similarly, the coefficient value of non-renewable energy consumption has also positive impact on CO2 emissions in developing countries. The results of CCE-MG estimator show that non-renewable energy consumption has positive and significant association with C02 emissions in developing countries. The positive sign indicates that developing countries are fulfilling their energy requirement with major share of non-renewable energy. As, developing countries have not much advanced technology that's why these economies accelerate their sectors with non-renewable energy. In this regard, non-renewable energy consumptions positively contribute to environmental degradation in the developing nations of Asia. Additionally, the coefficient of non-renewable energy consumption is equal to 0.858, meaning that a 1% increase in renewable energy consumption may increase a CO2 emission 0.858%. This long-run positive impact of non-renewable energy consumption on carbon emissions is supported by the study by Sahoo and Sahoo (2022) for India, Nathaniel and Iheonu (2019) for Africa, Y. Chen, Zhao, Lai, Wang, and Xia (2019) for China, as well as Dogan and Ozturk (2017) for USA.

Table 7: CCE-MG results for Model 1

Variables	Coef.	Std. Err.	Z	P>|z|	[95% Conf.	Interval]
LRE	-1.844158	1.694804	-1.09	0.007***	-5.165912	1.477597
LNE	-.0559939	.3633101	-0.15	0.002***	-.7680686	.6560808
LNR	.8289062	.7352075	1.13	0.000***	-.6120741	2.269886
_cons	3.171044	4.716496	0.67	0.001***	-6.073118	12.41521
Wald chi2 (3)	49.54			**Prob > chi2**	0.0002	
			CCE-MG results for Model 2			
Variables	**Coef.**	**Std. Err.**	**Z**	**P>|z|**	**[95% Conf.**	**Interval]**
LRE	1.214666	.806754	1.51	0.002***	-2.795875	.3665427
LNE	-.014864	.0556513	-0.27	0.059*	-.1239385	.0942105
LNR	.8588792	.2109473	4.07	0.000***	.4454301	1.272328
_cons	3.679759	1.491955	2.47	0.014**	.7555814	6.603936
Wald chi2(3)	17.01			**Prob > chi2**	0.0007	

4.5 D-H granger causality results of model 1 & 2 for developing countries

This sub-section presents the causal relationship among the variables of model 1 for developing countries by using D-H panel granger causality test. The results in Table 8 show that LNE Granger is caused without feedback by LGDP and LNR. This connection implies that nuclear energy consumption has an impact on economic growth in developing countries. The bidirectional causal relationship between LNE and LRE suggests that that both types of energy in model 1 contribute to each other in developing nations. Furthermore, LNR has unidirectional causal relationship with economic growth without any feedback. Also, renewable energy consumption has unidirectional relationship with economic growth in developing countries. So, it has been cleared that all type of energy significantly contributes to economic growth of these developing countries of Asia.

In model 2 for developing countries by using D-H panel granger causality test. The results in Table show that there is a bi-directional causal relationship between LNE and LCO2, LRE and LCO2 as well as LRE and LNE in developing countries. Interestingly, there is no evidence of causal relationship between LCO2 and LNR in these developing countries of Asia. Further, it is implied that renewable energy and nuclear energy consumption has significant relationship with carbon emission in developing countries.

Table 8: D-H granger causality results for Model 1

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LNE ≠ LGDP	4.07982	2.83921	0.0045
LGDP ≠ LNE	1.65562	-0.84632	0.3974
LNR ≠ LGDP	3.80085	2.42197	0.0154
LGDP ≠ LNR	2.05643	-0.23468	0.8145
LRE ≠ LGDP	4.14592	2.94749	0.0032
LGDP ≠ LRE	1.57715	-0.96460	0.3347
LNR ≠ LNE	5.39242	4.83477	0.0000
LNE ≠ LNR	4.44335	3.39189	0.0007
LRE ≠ LNE	4.52224	3.51183	0.0004
LNE ≠ LRE	3.84580	2.48344	0.0130
LRE ≠ LNR	2.16140	-0.07482	0.9404
LNR ≠ LRE	6.18864	6.05843	0.0000
D-H granger causality results for Model 2			
Null Hypothesis:	**W-Stat.**	**Zbar-Stat.**	**Prob.**
LNE ≠ LCO2	4.33699	3.23019	0.0012
LCO2 ≠ LNE	3.72691	2.30268	0.0213
LNR ≠ LCO2	7.34942	7.82624	0.0000
LCO2 ≠ LNR	1.89905	-0.47436	0.6352
LRE ≠ LCO2	3.49254	1.95244	0.0509
LCO2 ≠ LRE	4.46829	3.43844	0.0006
LNR ≠ LNE	5.39242	4.83477	0.0000
LNE ≠ LNR	4.44335	3.39189	0.0007
LRE ≠ LNE	4.52224	3.51183	0.0004
LNE ≠ LRE	3.84580	2.48344	0.0130
LRE ≠ LNR	2.16140	-0.07482	0.9404
LNR ≠ LRE	6.18864	6.05843	0.0000

5. Conclusion and Policy Recommendations

CCE-findings MG's for the perspective of developing countries showed that the long run coefficient value of nuclear energy consumption (LNE) is significantly negative in model 1, indicating that an increase in nuclear energy consumption reduces economic growth in developing countries by -.055 percent in the long run. Furthermore, in developing nations, the coefficient value of nonrenewable energy consumption produces findings that are diametrically opposed to those of nuclear energy consumption and renewable energy consumption. It is evident from the findings of the CCE-MG estimator that nonrenewable energy consumption has a positive and statistically significant relationship with economic development in emerging nations. According to this good indicator, emerging nations are meeting their energy requirements with a significant proportion of nonrenewable energy.

In the case of model 2, the long run coefficient value of nuclear energy consumption (LNE) is substantially negative in model 2, indicating that the increase in nuclear energy consumption reduces carbon emissions in the long run by -.0148 percent for developing nations, according to the model. The fact that nuclear energy consumption has a negative impact on CO2 emissions in emerging nations shows that, since nuclear energy consumption is a component of renewable and clean energy, the effect is negative in these growing Asian economies. On the basis of the findings, the research suggested that the government and stakeholders should place a strong emphasis on renewable energy sources in order to spur economic development, while at the same time implementing environmental laws in order to preserve the natural environment.

References

Abbasi, M. A., Parveen, S., Khan, S., & Kamal, M. A. (2020). Urbanization and energy consumption effects on carbon dioxide emissions: evidence from Asian-8 countries using panel data analysis. *Environmental Science and Pollution Research, 27*(15), 18029-18043.

Ahmad, A., Zhao, Y., Shahbaz, M., Bano, S., Zhang, Z., Wang, S., & Liu, Y. (2016). Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. *Energy Policy, 96*, 131-143. doi:10.1016/j.enpol.2016.05.032

Al-Mulali, U. (2014). Investigating the impact of nuclear energy consumption on GDP growth and CO2 emission: A panel data analysis. *Progress in Nuclear Energy, 73*, 172-178. doi:10.1016/j.pnucene.2014.02.002

Alam, A. (2013). Nuclear energy, CO2 emissions and economic growth: the case of developing and developed countries. *Journal of Economic Studies, 40*(6), 822-834. doi:10.1108/JES-04-2012-0044

Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics, 69*(11), 2255-2260. doi:10.1016/j.ecolecon.2010.06.014

Azam, A., Rafiq, M., Shafique, M., Zhang, H., & Yuan, J. (2021). Analyzing the effect of natural gas, nuclear energy and renewable energy on GDP and carbon emissions: A multi-variate panel data analysis. *Energy, 219*, 119592. doi:10.1016/j.energy.2020.119592

Baek, J., & Pride, D. (2014). On the income–nuclear energy–CO2 emissions nexus revisited. *Energy Economics, 43*, 6-10. doi:10.1016/j.eneco.2014.01.015

Bashir, A., Susetyo, D., Suhel, S., & Azwardi, A. (2021). Relationships between urbanization, economic growth, energy consumption, and CO 2 emissions: empirical evidence from Indonesia. *The Journal of Asian Finance, Economics and Business, 8*(3), 79-90. doi:10.13106/jafeb.2021.vol8.no3.0079

Bekhet, H. A., & Othman, N. S. (2018). The role of renewable energy to validate dynamic interaction between CO2 emissions and GDP toward sustainable development in Malaysia. *Energy economics, 72*, 47-61. doi:10.1016/j.eneco.2018.03.028

Bélaïd, F., & Youssef, M. (2017). Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria. *Energy policy, 102*, 277-287. doi:10.1016/j.enpol.2016.12.012

Bilgili, F., Koçak, E., & Bulut, Ü. (2016). The dynamic impact of renewable energy consumption on CO2 emissions: a revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews, 54*, 838-845. doi:10.1016/j.rser.2015.10.080

Chen, Y., Zhao, J., Lai, Z., Wang, Z., & Xia, H. (2019). Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO2 emissions: Evidence from a regional panel analysis. *Renewable energy, 140*, 341-353. doi:10.1016/j.renene.2019.03.058

Chen, Z., & Zhou, M. (2021). Urbanization and energy intensity: Evidence from the institutional threshold effect. *Environmental Science and Pollution Research, 28*(9), 11142-11157.

Conceiçao, P. (2019). *Beyond income, beyond averages, beyond today: inequalities in human development in the 21st century. human development report 2019*. Retrieved from

Dogan, E., & Ozturk, I. (2017). The influence of renewable and non-renewable energy consumption and real income on CO2 emissions in the USA: evidence from structural break tests. *Environmental Science and Pollution Research, 24*(11), 10846-10854.

Dogan, E., & Seker, F. (2016). Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy. *Renewable Energy, 94*, 429-439. doi:10.1016/j.renene.2016.03.078

Dong, K., Sun, R., Jiang, H., & Zeng, X. (2018). CO2 emissions, economic growth, and the environmental Kuznets curve in China: what roles can nuclear energy and renewable energy play? *Journal of Cleaner Production, 196*, 51-63. doi:10.1016/j.jclepro.2018.05.271

Friedman, M. (1937). The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the american statistical association, 32*(200), 675-701.

Iwata, H., Okada, K., & Samreth, S. (2010). Empirical study on the environmental Kuznets curve for CO2 in France: the role of nuclear energy. *Energy policy, 38*(8), 4057-4063. doi:10.1016/j.enpol.2010.03.031

Lee, S., Kim, M., & Lee, J. (2017). Analyzing the impact of nuclear power on CO2 emissions. *Sustainability, 9*(8), 1428. doi:10.3390/su9081428
Ma, T., Østergaard, P. A., Lund, H., Yang, H., & Lu, L. (2014). An energy system model for Hong Kong in 2020. *Energy, 68*, 301-310. doi:10.1016/j.energy.2014.02.096
Magazzino, C., Mele, M., Schneider, N., & Vallet, G. (2020). The relationship between nuclear energy consumption and economic growth: evidence from Switzerland. *Environmental Research Letters, 15*(9), 0940a0945. doi:10.1088/1748-9326/abadcd
Murshed, M. (2021). Modeling primary energy and electricity demands in Bangladesh: an autoregressive distributed lag approach. *Sustainable Production and Consumption, 27*, 698-712. doi:10.1016/j.spc.2021.01.035
Murshed, M., & Alam, M. (2021). Estimating the macroeconomic determinants of total, renewable, and non-renewable energy demands in Bangladesh: the role of technological innovations. *Environmental Science and Pollution Research, 28*(23), 30176-30196.
Naqvi, S. A. A., Shah, S. A. R., Anwar, S., & Raza, H. (2021). Renewable energy, economic development, and ecological footprint nexus: fresh evidence of renewable energy environment Kuznets curve (RKC) from income groups. *Environmental science and pollution research, 28*(2), 2031-2051.
Nathaniel, S. P., & Iheonu, C. O. (2019). Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption. *Science of the Total Environment, 679*, 337-345. doi:10.1016/j.scitotenv.2019.05.011
Nawaz, M. A., Hussain, M. S., & Hussain, A. (2021). The Effects of Green Financial Development on Economic Growth in Pakistan. *iRASD Journal of Economics, 3*(3), 281–292-281–292. doi:10.52131/joe.2021.0303.0044
Nazlioglu, S., Lebe, F., & Kayhan, S. (2011). Nuclear energy consumption and economic growth in OECD countries: Cross-sectionally dependent heterogeneous panel causality analysis. *Energy Policy, 39*(10), 6615-6621. doi:10.1016/j.enpol.2011.08.007
Payne, J., & Taylor, J. (2010). Nuclear energy consumption and economic growth in the US: an empirical note. *Energy Sources, Part B: Economics, Planning, and Policy, 5*(3), 301-307. doi:10.1080/15567240802533955
Peimani, H. (2019). Financial barriers for development of renewable and green energy projects in Asia. In *Handbook of Green Finance* (pp. 15-34): Springer.
Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels.
Raza, S. A., & Shah, N. (2018). Testing environmental Kuznets curve hypothesis in G7 countries: the role of renewable energy consumption and trade. *Environmental Science and Pollution Research, 25*(27), 26965-26977.
Sahoo, M., & Sahoo, J. (2022). Effects of renewable and non-renewable energy consumption on CO2 emissions in India: empirical evidence from disaggregated data analysis. *Journal of Public Affairs, 22*(1), e2307. doi:10.1002/pa.2307
Sarkodie, S. A., & Adams, S. (2018). Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa. *Science of the total environment, 643*, 1590-1601. doi:10.1016/j.scitotenv.2018.06.320
Shahbaz, M., Raghutla, C., Chittedi, K. R., Jiao, Z., & Vo, X. V. (2020). The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. *Energy, 207*, 118162. doi:10.1016/j.energy.2020.118162
Shen, X., & Lin, B. (2021). Does industrial structure distortion impact the energy intensity in China? *Sustainable Production and Consumption, 25*, 551-562. doi:10.1016/j.spc.2020.12.012
Vo, D. H., Vo, A. T., Ho, C. M., & Nguyen, H. M. (2020). The role of renewable energy, alternative and nuclear energy in mitigating carbon emissions in the CPTPP countries. *Renewable Energy, 161*, 278-292. doi:10.1016/j.renene.2020.07.093
Wang, Q., & Wang, L. (2021). The nonlinear effects of population aging, industrial structure, and urbanization on carbon emissions: A panel threshold regression analysis of 137 countries. *Journal of Cleaner Production, 287*, 125381. doi:10.1016/j.jclepro.2020.125381
Wolde-Rufael, Y. (2010). Bounds test approach to cointegration and causality between nuclear energy consumption and economic growth in India. *Energy Policy, 38*(1), 52-58. doi:10.1016/j.enpol.2009.08.053
Xu, Y., Kang, J., & Yuan, J. (2018). The prospective of nuclear power in China. *Sustainability, 10*(6), 2086. doi:10.3390/su10062086

Yoo, S.-H., & Jung, K.-O. (2005). Nuclear energy consumption and economic growth in Korea. *Progress in Nuclear Energy, 46*(2), 101-109. doi:10.1016/j.pnucene.2005.01.001