THE RELATIONSHIP BETWEEN ECONOMIC GROWTH, GLOBALIZATION AND RENEWABLE ENERGY USE AND CO2 EMISSIONS: EVIDENCE FROM ASIAN COUNTRIES AND IMPLICATIONS FOR VIETNAM

Tran Nguyen Chat[1], Hoang Khang[2], Le Hong Van[3]

(Foreign Trade University - Ho Chi Minh City Campus, Vietnam)

Abstract

The study combines IPAT and EKC models to assess the impact of socio-economic factors on CO2 emissions, using data from 35 Asian countries for the period 2000-2020. Tests such as Pesaran, CIPS, and Westerlund are applied to check the data properties, while the PMG method and Dumitrescu & Hurlin test help determine the relationship between factors in the short and long run. The results confirm that the EKC model is valid for Asian countries and show that globalization, population, and energy intensity increase CO2 emissions. In contrast, renewable energy has an impact on reducing emissions. For Vietnam, the study recommends investing heavily in renewable energy, reducing energy intensity, and requiring FDI enterprises to comply with environmental standards. The government should put greater focus on developing green technology and building sustainable policies.

Keywords: *CO2 emission, EKC model, PMG, Globalization*

[1] PhD. Tran Nguyen Chat, Foreign Trade University – Hochiminh City Campus, trannguyenchat.cs2@ftu.edu.vn

[2] Hoang Khang, Foreign Trade University – Ho Chi Minh City Campus (Vietnam), k60.2111113112@ftu.edu.vn

[3] PhD. Le Hong Van, Foreign Trade University – Ho Chi Minh City Campus (Vietnam), lehongvan.cs2@ftu.edu.vn

1. Introduction

The serious problems caused by climate change and global warming have required policymakers to focus on reducing greenhouse gas emissions, especially CO_2, the main cause of global environmental challenges. Since 1982, the global average temperature has increased by more than 0.5°C per decade due to increasing CO_2 emissions (WMO, 2023). Activities such as coal-fired power generation, carbon-intensive steel and cement production, motor vehicle use, and agricultural production, as well as daily activities such as cooking and heating, have been and are contributing significantly to air pollution, greenhouse gas emissions, and climate change. Meanwhile, Asia is one of the most vulnerable regions to climate change and is currently facing increasingly severe and unpredictable natural disasters, including heat waves, floods, and droughts (Maldonado and P.Gallagher, 2022). According to the IMF, temperatures in the region are rising twice as fast as the global average, increasing the frequency and severity of natural disasters. In South Asia, heavy rains have caused unprecedented mass migration, while water levels in the Mekong Delta are at record lows due to prolonged drought. Forecasts show that without timely adaptation measures, rice production in Southeast Asia could decline by up to 50% (World Bank, 2020). China, India, Pakistan and Bangladesh are currently the countries with the highest mortality rates due to air pollution in Asia, with more than 2.2 million deaths per year due to this cause (WHO, 2024).

Globalization, which began in the 1990s, has had a profound impact on many aspects, such as economics, politics and society. The expansion of international trade, along with cross-border capital flows and increased cooperation and competition, has helped many countries improve their income levels and thereby raise environmental awareness. Large corporations subsequently begin to adopt more environmentally friendly production methods and new technologies, especially green technology, which has also been more widely disseminated and contributed to reducing environmental degradation. However, globalization has also increased production, energy consumption and uncontrolled exploitation of resources, worsening the problem of environmental degradation. The "Pollution Haven" theory (Copeland & Taylor, 1994) suggests that strict environmental protection regulations in developed countries have encouraged large corporations to move production activities to developing countries with less environmental regulations to attract investment. In addition, the rapid economic growth seen in Asian countries in recent decades has also been accompanied by a significant increase in CO_2 emissions. Exemplary Asian countries such as China, India and Vietnam has achieved impressive economic progress thanks to strong industrialization policies, which inevitably increased their dependence on fossil energy and higher CO_2 emissions into the environment. The relationship between environmental quality and economic growth is explained by the Environmental Kuznets Curve, or EKC (Kuznets, 1955) hypothesis. This curve describes a non-linear inverted U-shaped relationship, in which environmental pollution increases as national income increases but declines at a certain level of income, due to technological progress and improved environmental standards.

A study on the relationship between globalization, economic growth, renewable energy use and CO_2 emissions is important in supporting governments and policymakers to develop more effective solutions to protect the environment and cope with climate change. This study assesses the relationship and impact of globalization, economic growth and other economic factors on CO_2 emissions in Asian countries, aiming to provide a comprehensive dataset to examine the relationship between these factors in different contexts. The research results provide broad generalizations and useful policy implications for Vietnam, as this country has many similarities in terms of economy, trade policy and environmental challenges with other countries in the region. From there, the study proposes research implications for policymakers in Asia in general and Vietnam in particular to move towards a more sustainable future for the region.

2. Hypothesis development

2.1. Literature review

Many studies have been conducted in different regions and countries around the world to gain a deeper understanding of the factors that influence CO_2 emissions and environmental quality. The studies consider the following three main groups of factors: economic factors, energy factors, and socio-demographic factors.

In the first group of factors, theoretical studies have shown the link between economic development and environmental pollution, mainly due to the use of polluting technology, over-exploitation of natural resources, increased emissions from industrialization, lack of awareness of environmental protection, and prioritizing economic growth. However, this factor also has the potential to improve the environment through promoting stricter environmental regulations, access to and application of clean technology, resource conservation, and raising public awareness of environmental issues (nguồn). GDP is the main measure used to evaluate economic development because it represents the size of income or economic activity. The Kuznets Curve (EKC) hypothesis was developed to study the relationship between economic growth and environmental quality and is derived from the EKC hypothesis of Kuznets (1955). The hypothesis is based on the explanation that initial economic growth accompanied by industrialization will simultaneously increase CO_2 emissions and income levels. In the later stages of industrialization, as income increases, environmental awareness increases and regulatory agencies become more effective, reducing pollution levels. These results confirm the inconsistency in the relationship between economic growth and environmental degradation (Li et al., 2016). Several studies have confirmed the EKC hypothesis with an inverted U-shaped relationship, suggesting that economic growth improves environmental quality, i.e. reduces emissions (Selden and Song, 1994; Cole, Rayner, and Bates, 1997). In contrast, Ekins (1997) found no EKC, suggesting that increased economic growth leads to greater environmental degradation. Moutinho, Varum, and Madaleno (2017) and Mrabet and Alsamara (2017) also show that the validity of the EKC hypothesis may vary depending on the country or countries studied. The relationship between CO_2 emissions and economic growth may appear as linear, U-shaped, inverted U-shaped, or any other shape. Based on the above literature, the empirical results show a diverse relationship. This may be due to the different sample selections, time periods, variables and analytical techniques (Begum et al., 2015).

In addition, globalization is also included when considering economic factors, as it affects the flows of trade, investment, and technology between countries. Globalization promotes the expansion of international trade, increases foreign investment, and facilitates countries' access to global markets, technology, and resources. In general, there are two main lines of research on globalization and its impact on the environment: there are positive or negative effects from globalization on CO_2 emissions and environmental quality. Representative of the first are Saud et al. (2019) and Le, Van and Bao (2018). They argue that globalization will introduce new technologies, reduce the use of traditional energy and increase the use of renewable resources, which helps reduce CO_2 emissions and improve environmental quality. Proponents of the second line are studies conducted by Shahbaz, Shahzad, and Mahalik (2018) for Japan and Majeed and Mazhar (2019) for a group of 155 countries. They theorize that because globalization increases the affordability and accessibility of goods and services, more fossil fuel will be used and wastes generated from the processes of production, transportation and consumption, leading to negative impacts on the environment.

The second group mainly consists of studies on energy-related factors affecting CO2 emissions. Energy is considered the lifeblood of the economy, the most important tool for socio-economic development (Sahir and Qureshi, 2007). Many studies have been conducted on both renewable and non-renewable energy sources, including coal, oil, gas, nuclear, solar, wind, and other sources. Among them, renewable energy is receiving attention because of its potential to reduce CO2 emissions. Some studies that mention the positive impacts of renewable energy consumption include Bélaïd and Youssef (2017) in Algeria; Dong, Sun, and Dong (2018) in China; Bekun, Alola, and Sarkodie (2019) in 16 EU countries; Bhattacharya, Awaworyi Churchill, and Paramati (2017) in 85 countries worldwide. In addition, energy intensity is also an energy factor of interest, as Dong, Dong, and Dong (2019) pointed out that energy intensity is an important factor to control greenhouse gas emissions. In addition, according to Xu and Lin (2015) and Xu and Lin (2017), energy intensity can also be considered a determinant of CO2 emissions.

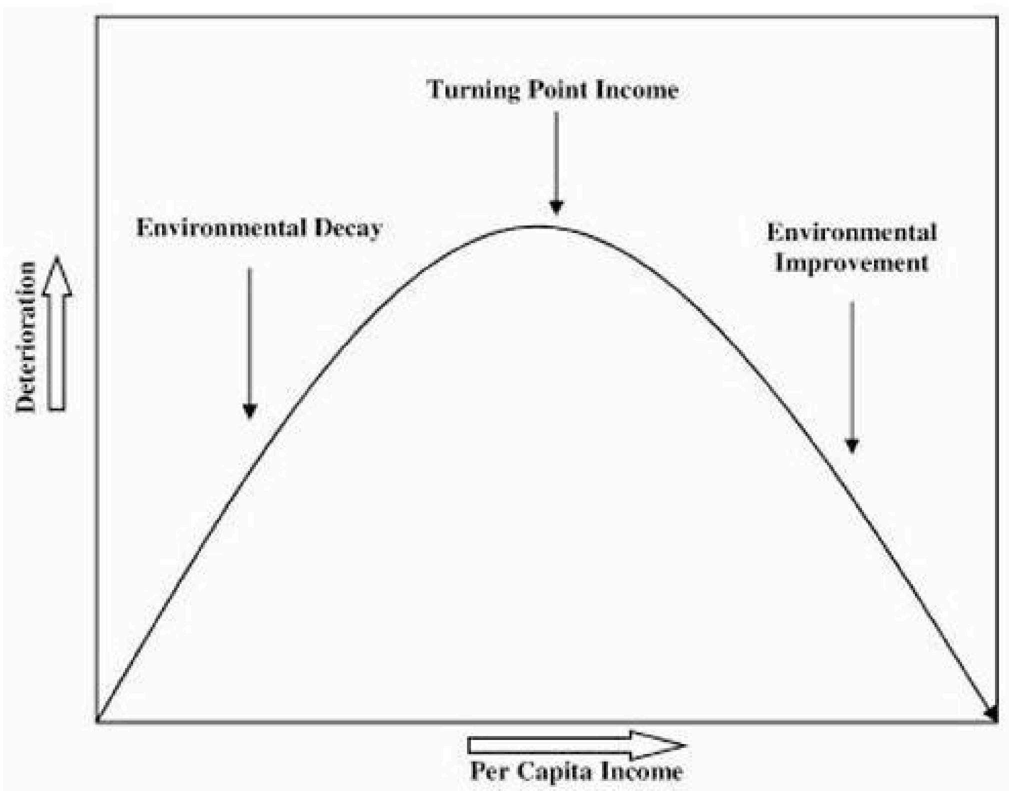
The last group is socio-demographic factors. From the beginning of research on the relationship of different factors to the environment, the IPAT research framework has confirmed that population size and growth rate are significant contributors to environmental degradation (Ehrlich and Holdren, 1971). Many studies have shown that population growth is harmful for the environment, such as Aluko, Opoku and Acheampong (2022), and is positively related to CO2 emissions (Zaba and Clarke, 1994). Hamilton and Turton (2002) concluded that population growth is one of the two main factors increasing carbon emissions in OECD countries. Chandra Voumik and Sultana (2022) conducted a study on BRICS countries between 1972 and 2021, coming to a similar conclusion.

In general, there are studies examining the relationship between CO2 emissions and economic growth, but not many have specifically examined the role of globalization in enhancing or reducing CO2 emissions, and some data sets are not up-to-date while the Asian countries studied are among the countries with high annual economic integration rates. This study uses data from the World Bank KOF Index of Globalisation updated up to 2020. In addition, the study combines the ideas of the EKC model and IPAT to test the validity of this model in the Asian scope, in the context of current research results of the EKC model are still controversial.

2.2. Environmental Kuznets Curve (EKC):

In 1955, Simon Kuznets introduced the Environmental Kuznets Curve (EKC), which describes the relationship between economic development and environmental pollution, similar to the curve describing the relationship between inequality and economic development previously proposed (Kuznets, 1955). The EKC curve is shown in Figure 1:

Figure 1: The Environmental Kuznets Curve (Yandle, Bhattarai and Vijayaraghavan, 2004)



The relationship between environmental pollution and income is represented by a curved U. The turning point in Table 1 shows the point at which income can change the relationship between environmental pollution and economic development. Higher income levels will lead to economic development, which has a positive effect on environmental quality. To explain the shape of the EKC, Selden and Song (1994) explain as follows: When the quality of life in a country reaches a sufficiently high level, people will demand better living conditions. Environmental quality is considered a luxury good, because the value of the elasticity of demand for environmental goods is greater than one. In other words, when income reaches a certain threshold, people will be willing to pay for a cleaner living environment.

Grossman and Krueger (1995) argue that economic activities can affect the environment through three effects. First is the scale effect, with economic growth in its early stages and abundant natural resources, increased production and income reduce environmental quality. Second, the initial industrialization process will require more resource consumption and increase environmental emissions, but later, with increased income, the economic structure will shift from industries with high energy intensity to industries focused on services and technology. The third effect is the technology effect, when the shift of industries, as well as the dissemination of technology and information, reduce economic growth's energy consumption and increase labor productivity, thereby minimizing environmental degradation. Economic growth will encourage investment in environment-related research and development, and the invention of more environmentally techniques and practices.

2.3. STIRPAT model:

In recent decades, many studies have been conducted with various methods to assess the drivers of carbon dioxide emissions. Among those methods is the STIRPAT model, derived from the IPAT model by Ehrlich and Holdren (1971) which formalizes the theoretical relationship between population, human well-being, and environmental impacts. This equation is widely recognized and used for analyzing the effect of population and population growth on the environment (Harrison & Pearce, 2000). Currently it is still used to analyze the driving forces of environmental change (York et al., 2002).

The IPAT model is mathematically the product of three factors: P, A and T, represented as follows:

$$I = P \times A \times T \; (I = PAT) \quad (1)$$

where I is environmental impact, P is population, A is wealth, and T is technology. Wealth is usually measured by the national GDP per capita.

The original IPAT model assumes that population is the main driver of global environmental change. However, it possesses several limitations. First, it assumes the proportional impact of population, wealth, and technology factors on the environment, which means if there is 2 times increase in income, the effect on environment will increase twofold as an example, assuming all other factors remain constant. Second, IPAT does not allow for empirical testing of the hypothesis (York, Rosa, and Dietz 2003). To overcome these limitations, Dietz and Rosa (1997) modified IPAT into the stochastic STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model. It allows for statistical testing and analysis of the disproportionate impact of population and wealth on the environment.

The STIRPAT equation is presented as follows:

$$I_{it} = \alpha_{it} P_{it}^{\beta_1} A_{it}^{\beta_2} T_{it}^{\beta_3} \varepsilon_{it} \quad (2)$$

where I, P, A and T are the same factors as in the IPAT model. a is a constant, b, c and d are parameters that can be estimated using statistical tools. To facilitate estimation and hypothesis testing, York, Rosa and Dietz (2003) proposed transforming the model into logarithmic form. The following modified model is shown:

$$lnI_{it} = \alpha_{it} + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnT_{it} + \varepsilon_{it} \quad (3)$$

The subscript i denotes that these quantities (I, P, A, and T) vary with the unit of observation; t denotes years; b, c, and d are the exponents of P, A, and T, respectively; e is the error term, and a is a constant. This equation represents a linear relationship between population, wealth, and technology.

3. Research method

3.1. Model & Data

This study combines the IPAT equation's existing variables with factors known to have an impact on CO2 emissions, including Globalization (GI) (Cemalettin Kalaycı, 2018; Muhammad, 2019) and Renewable Energy Use (REC) (Sahar, 2014; Dervis, 2021) to test the EKC model's validity and assess the long-term impact of socio-economic factors on CO2 emission in Asian countries. The research hypothesis proposes that Globalization (GI), Energy Intensity (EI), Population (POP) and GDP (representing T, P and A of the IPAT model (Danish, 2020; Hassan, 2024; Kim, 2020) increase CO2 emission while Renewable Energy Consumption (REC) and GDP squared (GDP^2) increase will reduce CO2 emission into the environment. The model specification is as follows:

$$CO2 = \alpha_{xt} + \beta_1 GI_{xt} + \beta_2 GDP_{xt} + \beta_3 GDP_{xt}^2 + \beta_4 POP_{xt} + \beta_5 EI_{xt} + \beta_6 REC_{xt} + \varepsilon_{xt}$$

where CO2 is measured in kilotons, GI is retrieved from the KOF Globalization Index, GDP and GDP^2, expressed as annual rates, represent the impact of economic growth in the short and long term, POP is calculated by the total population of each country, EI is the energy intensity, and

REC is the percentage of renewable energy in total final energy consumption. The study uses a dataset of 35 Asian countries for 21 years from 2000-2020 collected from WDI and KOF. To reduce the data's standard deviation in the model, the study uses ln for all variables except for REC (with values lower than 1). The econometric equation and descriptive statistics are presented as follows:

$$lnCO2_{xt} = \alpha_{xt} + \beta_1 lnGI_{xt} + \beta_2 lnGDP_{xt} + \beta_3 lnGDP^2_{xt} + \beta_4 lnPOP_{xt} + \beta_5 lnEI_{xt} + \beta_6 REC_{xt} + \varepsilon_{xt}$$

Table 1: Descriptive statistics of data

Variable	Obs	Mean	Std. Dev.	Min	Max
lnCO2	735	11.1716	1.844406	7.582229	16.20836
lnGI	735	4.071601	.2074511	3.465736	4.430817
lnGDP	735	6.777062	1.980262	2.152392	11.89735
lnGDP2	735	49.84467	27.79151	4.632792	141.547
lnPOP	735	12.59406	2.688315	6.248607	18.61939
lnEI	735	1.66529	.4429735	.6418539	3.415757
REC	735	17.20789	22.44068	0	91.3

3.2. Research methods:

3.2.1. Cross-dependence statistics:

Pesaran (2004) developed the CD statistic based on the LM statistic by Breusch and Pagan (1980), which has many advantages over the latter, because it provides more accurate mean values when the number of time observations (T) and the number of cross-sectional units (N) are held constant (To et al. 2019). The CD statistic can be applied to both homogeneous and heterogeneous models, as well as to non-stationary data, allowing for flexible and efficient testing of cross-sectional dependence in panel data. This increases the accuracy when applied to many different models.

The formula of Pesaran's cross-sectional cointegration test (CD test) is defined as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \right) \simeq N(0, 1)$$

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} \hat{\mu}_{it} \hat{\mu}_{jt}}{\sqrt{\sum_{t=1}^{T} \hat{\mu}_{it}^{2}} \sqrt{\sum_{t=1}^{T} \hat{\mu}_{jt}^{2}}}$$

- CD is the CD test statistics.
- T is the number of observations over time.
- N is the number of cross-sectional units (such as countries, regions, etc.).
- ρ^ij is the estimate of the correlation between units i and j.

When both NNN and TTT are large, this statistic follows a normal distribution with an expectation of 0 and a variance of 1. This allows for testing the hypothesis that there is no cross-sectional dependence between units in the panel data.

3.2.2. Panel unit root test:

Once the existence of cross-sectional dependence in the model has been confirmed, first-generation unit root tests such as LLC (Levin, Lin, and Chu) and IPS (Im, Pesaran, and Shin) become inappropriate, because they do not take this issue into consideration. Therefore, the study chose to use the second-generation unit root test, CIPS (Cross-sectional Im, Pesaran, and Shin), to determine the stationarity of the data, which is considered more appropriate. The CIPS (Cross-sectional Im, Pesaran and Shin) test equation to test the stationarity of the data in panel data can be described as follows:

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} \hat{\tau}_i$$

Where:

- N is the number of units in the panel
- $\hat{\tau}_i$ is the unit root test statistic for each unit i, calculated using the IPS test.

3.2.3. Cointergration test:

Which test method is used will depend on the presence of cross-sectional dependence (CSD) in the data. If CSD is detected, the cointegration test proposed by Westerlund (2007) will need to be applied. Westerlund's test is designed to address problems associated with CSD, increasing the cointegration test's precision. It consists of four tests, each of which is based on the idea that time series without a unit root converge to a long-run equilibrium. Conversely, if CSD is not present, the cointegration test by Pedroni (1999, 2004) has been shown to be more appropriate. Pedroni's method, consisting of seven tests, some of which indicate cointegration by examining regressions between variables in the model, is more suitable in cases where there is no cross-sectional dependence and will provide insight into the relationship between variables.

3.2.4. PMG Estimation:

Developed by Pesaran, Shin and Smith in 1999, PMG (Pooled Mean Group) is an estimation method used in time series and panel data analysis, based on Mean Group (MG) and Fixed Effects (FE) estimations. PMG allows for the incorporation of different short-term factors across observation units (such as countries or industries), while it also assumes that long-term factors are constant. This is the highlight of PMG compared to other methods, as it allows for flexibility in the short run while maintaining the general relationship in the long run.

The formula of PMG (Pooled Mean Group) is based on the Autoregressive Distributed Lag Model (ARDL) and presented as follows:

$$y_{it} = \sum_{j=1}^{p} \phi_{ij} y_{i,t-j} + \sum_{k=0}^{q} \beta_{ik} x_{i,t-k} + \mu_i + \epsilon_{it}$$

Trong đó:

- y_{it} is the unit i's dependent variable at time t.
- x_{it} is one or more explanatory variables (independent variables) at time t.
- p và q are the dependent and independent variables' lags.
- ϕ_{ij} are the estimated parameters related to the lags of the dependent variable.
- β_{ik} are the explanatory variables' estimated parameters.
- μ_i is the for unit i's fixed effect coefficient, representing the unobserved spatial factors.
- ϵ_{it} is the residual of the model, assumed to be normally distributed and uncorrelated.

3.2.5. Dumitrescu-Hurlin Panel Casuality Test:

Dumitrescu and Hurlin (2012) developed a method for testing causality in panel data called the Dumitrescu-Hurlin Panel Causality Test. This method aims to test the causal relationship between variables in a panel data, where there may be differences in causality across different units of observation (countries, industries, etc.). This causality test is an extension of the traditional Granger causality test for panel data, and it is suitable for cases where the causal relationship may be heterogeneous across units of observation (heterogeneous causality).

Assuming there are two variables X and Y, and the research wants to know whether X causes Y in the Granger sense in a panel data. The Granger causality regression model for each unit i can be written as:

$$Y_{i,t} = \alpha_i + \sum_{k=1}^{K} \beta_{i,k} Y_{i,t-k} + \sum_{k=1}^{K} \gamma_{i,k} X_{i,t-k} + \epsilon_{i,t}$$

Where:

- $Y_{i,t}$ is the unit i's dependent variable at time t.
- $X_{i,t}$ is the explanatory variable (independent variable).
- K is the model lag.
- α_i, $\beta_{i,k}$, $\gamma_{i,k}$ are the estimated parameters.

The objective is to test the null hypothesis that X does not cause Y in the Granger sense given that the units in the sample:

$$H_0: \gamma_{i,k} = 0 \quad \forall i$$

The alternative hypothesis supposes that there are some units that have a causal relationship:

$$H_1: \gamma_{i,k} \neq 0 \quad for\ some\ unit\ i$$

4. Result

4.1. Panel data tests result

The cross-country dependence test results (Table 2) confirm the inter-relationship between countries in the model, meaning that changes in one country or group can affect other countries or groups. In the context of this study, which examines Asian countries, cross-country dependence may reflect economic, trade or environmental linkages between them.

Table 2: Pesaran's test of cross sectional independence result

Pesaran's test of cross sectional independence = 10.214					Pr = 0.0000	
Variable	lnCO2	lnGI	EI	lnGDP2	lnGDP	lnPOP	REC
CD-test	75.409***	92.555***	39.035***	102.11***	102.667***	64.077***	4.379***

When the existence of cross-sectional dependence in the model is proven, the first generation panel unit root test such as LLC (Levin, Lin, and Chu) or IPS (Im, Pesaran, and Shin) is no longer suitable because the above tests do not take this issue into account. The study therefore uses the more appropriate second-generation panel unit root test CIPS (Cross-sectional Im, Pesaran and Shin) to determine the stationarity of the data. The results of the YYY table show that all variables in the model are stable at I(1).

Table 3: Cross-Sectionally Augmented IPS test result

Varial	Level	First Difference	Conclusion
lnCO2	-1.771	-3.805***	I(1)
lnGI	-2.573	-4.305***	I(1)
lnEI	-2.485	-3.972***	I(1)
lnGDP2	-2.508	-3.406***	I(1)
lnGDP	-2.546	-3.508***	I(1)
lnPOP	-2.631*	-3.536***	I(1)
lnREC	-1.397	-3.337***	I(1)

*The significant values at the 10%, 5%, and 1% levels are -2.63, -2.71 and -2.85. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.*

To test for cointegration in the model of cross-sectional dependence, Westerlund cointegration test is proven to be more suitable than Kao or Pedroni test. Results in Table 4 also confirm the long-run relationship between variables in the model with prob = 0.0153 < 0.05.

Table 4: Westerlund cointegration test result

Westerlund test for cointegration		
	Statistic	p-value
Variance ratio	-2.163	0.0153

4.2. Short & long run relationship regression:

To determine the short- and long-term relationship of CO2 emission with independent variables in the model, the study performed regression using Pooled Mean Group and Dumitrescu-Hurlin causality test. Results are shown in Tables 5 and 6 as follows:

Table 5: Pool Mean Group Regression Result

Dependence Variable: lnCO2	Coef.	P>z
Long-run estimation		
lnGI	.6336593	0.000
lnEI	.6597966	0.000
lnGDP2	-.0100832	0.013
lnGDP	.6354902	0.000
lnPOP	.3411212	0.000
REC	-.0259502	0.000
Short-run estimation		
__ec	.2541121	0.000
lnGI D1.	.245043	0.012
lnEI D1.	.4485558	0.000

lnGDP2 D1.	.0264655	0.224
lnGDP D1.	.4815216	0.486
lnPOP D1.	.6738318	0.229
REC D1.	-.0817616	0.036
_cons	.0454251	0.244

Table 6: Dumitrescu-Hurlin Panel Causality Test

Alternate hypothesis	Z-bar tilde	p-value
lnCO2 does Granger-cause lnGDP for at least one panel	5.7397	0.0000
lnGDP does Granger-cause lnCO2 for at least one panel	9.4677	0.0000
lnCO2 does Granger-cause lnGI for at least one panel	7.7638	0.0000
lnGI does Granger-cause lnCO2 for at least one panel	1.2638	0.2063
lnCO2 does Granger-cause lnEI for at least one panel	5.8592	0.0000
lnEI does Granger-cause lnCO2 for at least one panel	6.0903	0.0000
lnCO2 does Granger-cause lnPOP for at least one panel	7.6484	0.0000
lnPOP does Granger-cause lnCO2 for at least one panel	6.4354	0.0433
lnCO2 does Granger-cause REC for at least one panel	.	.
lnREC does Granger-cause lnCO2 for at least one panel	.	.

When examining the regression results presented in table 5, it can be seen that the error correction term has a value of 0.2541 and is statistically significant at the 1% level, indicating the speed of adjustment to the long-run equilibrium state of the dependent variable when there is a change or shock to the independent variables. About 25.41% of the deviation from the long-run equilibrium state will be adjusted each year, meaning that the adjustment speed is slow, because only a quarter of the deviation is corrected in each period. It will take many periods (years) for the deviation to completely disappear and the system to return to equilibrium. The long-run PMG regression results indicate a positive relationship between GDP and CO_2 emission with a coefficient of 0.635, meaning that when other factors are constant, when GDP increases by 1%, CO_2 emissions into the environment will increase by 0.635%. As the Asian economies continue to grow, the impact of GDP will reverse and help reduce CO_2 emissions at the 1% level. This result proves to be consistent with the hypothesis of the EKC model in the context of selected Asian countries and studies by Muntasir (2020) and Ilhan (2024) also shared similar findings. However, in the short term, there are insufficient statistical evidence for both GDP and GDP^2. This can be explained by the fact that CO_2 emissions are often associated with industrial activities and energy consumption, which are highly inertial and not easily changed immediately when GDP increases or decreases. Energy production and consumption projects usually have longer cycles, so short-term GDP changes are difficult to reflect in emissions, compared to the long-term relationship. The study results also show similar results for population, mainly because population growth leads to increased demand for energy and resources. As the population increases, the number of consumers and the demand for goods also increase, leading to higher energy consumption. Furthermore, as the population increases in the long run, there may be urban expansion and infrastructure development, which often leads to increased use of fossil fuels and increased CO_2 emissions. Industrial activities, transportation, and electricity demand all increase as the population increases, putting greater pressure on the environment. (Muhammad, 2021; Abdul, 2021). The panel cointegration test confirmed the existence of a long-run relationship between variables. Furthermore, the Dumitrescu-Hurlin causality test provided evidence for a bidirectional causal relationship between CO_2 emissions, GDP and population.

The results of the study show that the investigated factors all contribute to carbon emissions in Asia in the short run. According to the World Bank, Vietnam's GDP has increased from USD 194 billion in 2010 to USD 409 billion in 2021, corresponding to an average growth rate of about 6.6% per year. Meanwhile, according to the General Statistics Office, Vietnam's population has increased from 87 million in 2010 to 98 million in 2021. This has led to higher energy consumption and increased CO_2 emissions. In 2020, Vietnam's CO_2 emissions reached about 258 million tons, implying that as Vietnam's economy and population continue to grow, regulatory policies to reduce emissions, such as investing in green technology and renewable energy, as well as implementing sustainable development and management measures, are needed to control this impact. Globalization is shown to increase CO_2 emissions in both the short and long term according to PMG results, but the impact is stronger in the long term due to the process of deep economic integration and long-term production expansion. In the short term, as countries integrate into the global economy, trade flows and foreign investment increase rapidly, leading to the expansion of production and consumption. This is often accompanied by an increase in demand for energy and natural resources, especially fossil fuels, which in turn increases CO_2 emissions. However, at this stage, the process of development and production transition is still limited, and the impact on emissions is not yet maximal. In the long term, as globalization progresses more strongly, countries gradually depend more on international trade and global supply chains. This causes countries, especially developing countries, to increase their industrial scale, export goods and import more fossil fuels to maintain economic growth. Furthermore, international transport – one of the largest sources of emissions – has increased significantly as more goods are produced and transported across borders. Industrialization and urbanization driven by globalization have also led to infrastructure development, which requires large amounts of resources and energy, further increasing CO_2 emissions. TTT GGG's study also showed similar results when examining the impact of globalization at ABC. In the context of globalization, Vietnam will also face both challenges and opportunities. Increased trade and foreign investment can lead to increased production and energy consumption, increasing CO_2 emissions. Export turnover has increased from 96 billion USD in 2010 to 336 billion USD in 2021, according to the General Statistics Office. This leads to the expansion of production and consumption, putting great pressure on energy demand, especially fossil fuels. As countries integrate into the global economy, trade flows and foreign investment increase rapidly, leading to increased energy consumption demand. However, this is also an opportunity for technology transfer and the application of sustainable production measures, requiring Vietnam to take advantage of this opportunity to improve production processes and reduce CO_2 emissions.

Energy intensity is also shown to have an important impact on CO_2 emissions, with reducing energy intensity helping to reduce emissions in both the short and long term, with a stronger impact in the long term. Similar results are also presented in the TTT study. Although reducing energy intensity in the short term can reduce emissions, the change may not be large enough or fast enough due to limitations in adopting new technologies or improving production processes. The study also demonstrates a bidirectional effect of energy intensity and CO_2 emissions with a coefficient of prob=0.000 in the Dumistrescu & Hurlin test. In the long term, the impact of reducing energy intensity is more significant, as countries invest in cleaner and more efficient technologies. This not only contributes to reducing energy consumption but also improves production efficiency. Measures such as adopting renewable energy technology, optimizing production processes, and improving energy efficiency in industries will reduce dependence on fossil fuels, thereby reducing CO2 emissions in a sustainable manner. Furthermore, in the long term, reducing energy intensity can also generate momentum for a shift to sustainable development models, helping countries to reduce pollution, achieve their climate goals and enjoy long-term economic benefits with new employment opportunities and reduced public health costs due to pollution. Data from the Ministry of Industry and Trade shows that Vietnam's energy intensity has decreased, from 0.62 toe/1,000 USD in 2010 to 0.49 toe/1,000 USD after a decade. This reduction reflects the Vietnamese government's efforts to improve energy efficiency and apply more advanced technologies in production. When energy intensity is reduced, it not only saves resources but also reduces CO2 emissions, however, the reduction in energy intensity may not happen quickly due to the continued dependence on older inefficient technology and production processes in Vietnam. Therefore, to further reduce energy intensity and CO2 emissions, Vietnam needs to increase investment in green, modern technology and energy saving solutions.

PMG regression results also show that the use of renewable energy has a direct impact on CO2 emissions because it directly replaces fossil energy sources, helping to reduce CO2 emissions immediately. In the short term, an increase in the use of renewable energy can lead to rapid emissions reductions, especially when renewable energy sources such as wind, solar or hydropower contribute to the national energy system. According to data from the Ministry of Industry and Trade of Vietnam, solar power capacity has increased sharply from 0 MW in 2017, to 16.5 GW by 2020. RECs also help reduce emissions in the long term, but the impact is minimal due to the the energy system's stability. When renewable energy consumption increases, countries need time to develop the necessary infrastructure and optimize renewable energy technologies. In addition, other factors such as population growth and increased energy demand have a long-term positive effect on CO2 emissions, thereby reducing the overall impact of RECs. This is also observed by Xiaotian Yang et al. (2022) in the context of OECD countries' CO2 emissions.

With high economic and population growth rates, many Asian countries are facing major environmental challenges with severe consequences, such as pollution and climate change, which can be attributed directly or indirectly to CO_2 emissions. By analyzing the relationship between different socio-economic factors and CO_2 emissions, the study offers several implications and recommendations for Asian governments in controlling their CO_2 emissions, especially Vietnam's. The development of green energy projects should be encouraged via financial incentives and policy-making. To hasten adaptation of green energy into all facets of society, including household use and industrial production, the government should develop appropriate infrastructure to integrate new renewable energy sources into the national power system. In addition, improving energy efficiency is crucial, especially in energy-intensive industries such as steel and cement production. The large-scale adoption of advanced, efficient technology and production processes by these industries and other will not only cut down on their overall energy consumption, but also their CO_2 emissions to the environment. In the context of Asian countries' ever-greater integration with the global market, Asian governments need to pursue sustainable trade and investment policies which can limit the harmful effects economic growth may have on the environment quality.

As economic growth and larger populations positively affect CO_2 emissions, Vietnam will encounter many difficulties in keeping its CO_2 emissions under control. In order to achieve this goal, Vietnam should continue to strongly promote the development of national renewable energy production. While Vietnam's growth in solar energy generation is a positive signal for the sector, this should be replicated with others, such as wind power and biomass, which still have many untapped potential. The overall goal is that these renewable energy sources will be able to displace reduce Vietnam's reliance on non-renewable fossil fuels as the main energy source. The government needs to create mechanisms to encourage domestic enterprises and foreign investors to invest in renewable energy projects through tax and financial incentives. Energy intensity in Vietnam also needs to be significantly reduced, especially in heavy industries. Policies that promote the adoption of advanced, energy-efficient technologies and stricter regulation of energy-intensive manufacturing sectors such as cement, steel, and chemicals are crucial. The government should focus on improving production processes, reducing energy consumption in manufacturing, and reducing emissions from fossil fuel consumption. While Vietnam's deep integration into the global economy has led to increased CO_2 emissions, it is also an opportunity for Vietnam to adopt green technology from developed countries, especially in export-oriented manufacturing.

The government should require FDI enterprises and inspect them regularly to ensure compliance with national environmental standards in manufacturing activities, while incentivizing usage of renewable energy and environmentally friendly technologies. With regards to population growth and urban expansion in Vietnam, ever-increasing pressure is put on the energy sector and resource extraction. Therefore, stricter policies on infrastructure development and pollution control should be enforced, ensuring that urbanization does not cause further environmental damage, as well as setting visions to create truly sustainable and environmentally-friendly urban areas in the near future to anticipate the population growth. Finally, Vietnam needs to focus on building sustainable development policies, in which economic growth goes hand in hand with environmental protection. This include initiatives on resource management, investment in green technology, and development of low-emission industries, helping Vietnam to more effectively tackle with future environmental challenges.

5. Recommendation

The rapid economic and population growth in Asia are causing the region to experience major environmental challenges, especially with regards to CO2 emissions. By analyzing the relationship between socio-economic factors and emissions, the study offers a number of recommendations for governments in controlling their CO2 emissions. Investment in green energy projects should be encouraged and appropriate infrastructure should be built to allow renewable energy sources to contribute to the national power system and displace polluting fossil fuels as the only considerable source of energy. In addition, a reduction in energy intensity, especially for industries such as steel and cement production, is essential. Adoption of advanced, efficient technology and production processes will not only save energy but also significantly reduce long-term CO2 emissions. Asian governments need to develop sustainable trade and investment policies to control emissions in the context of deepening globalization, thereby ensuring that economic growth does not cause further damage to the environment.

For Vietnam, rapid economic and population growth will pose many challenges in terms of CO2 emissions. In order to manage emissions, Vietnam needs to continue to strongly promote the development of renewable energy. Its recent achievements in solar energy generation are a positive signal, but this should be replicated with other sources, such as wind power and biomass. The government needs to create mechanisms to encourage domestic enterprises and foreign investors to invest in renewable energy projects through tax and financial incentives. Energy intensity in Vietnam also needs to be significantly reduced, especially in heavy industries. Policies that promote the adoption of advanced, energy-efficient technologies and stricter regulation of energy-intensive manufacturing sectors such as cement, steel, and chemicals are crucial. The government should focus on improving production processes, reducing energy consumption in manufacturing, and reducing emissions from fossil fuel consumption. While Vietnam's deep integration into the global economy has led to increased CO_2 emissions, it is also an opportunity for Vietnam to adopt green technology from developed countries, especially in export-oriented manufacturing. The government can require FDI enterprises to comply with higher environmental standards, while encouraging the use of renewable energy and environmentally friendly technologies in manufacturing activities. With regards to population growth and urban expansion in Vietnam, ever-increasing pressure is put on the energy sector and resource extraction. Smarter cities, using clean and energy-efficient technologies, with environmentally-friendly infrastructure and widespread public transport use should be the main focuses in Asian countries' urban planning. Stricter policies on infrastructure development and pollution control should also be enforced, ensuring that urbanization does not cause further environmental damage. Finally, Vietnam needs to focus on creating its sustainable development policies, which will find a balance between economic growth with environmental protection, such as initiatives on resource management, green technology and low-emission industries development, through which Vietnam will be able to more effectively tackle future environmental challenges.

6. Conclusion

Both IPAT and EKC models are used by the study to create a model and assess the short-term and long-term impacts of socio-economic factors on CO_2 emissions, using a dataset of 35 Asians countries, from 2000 to 2020, which is collected from WDI and KOF to ensure data integrity. The study employs the Pesaran cross-sectional dependence test, CIPS second-generation stationarity test and Westerlund cointegration test to verify the panel data's properties. The study then continues to estimate the long and short-run impact on the dependent variable and examines the short-run bidirectional relationship by combining the PMG and the

Dumitrescu & Hurlin test. The research results confirm the EKC model in the context of Asian countries, and verify that factors including globalization, population, and energy intensity have a positive impact on CO_2 emissions in the long run, while increasing the use of renewable energy will help reduce CO_2 emissions. The research results also demonstrate the impact of socio-economic factors on the dependent variable through the short-term PMG results and Dumitrescu & Hurlin test, thereby proposing policy implications for Asian countries in general and Vietnam in particular. In general, Asian governments need to encourage investment in renewable energy, improve energy efficiency in heavy industries, and build sustainable trade policies. In the context of Vietnam, with rapid economic and social development, it is important to promote wider usage of renewable energy sources such as wind power and biomass, reduce energy intensity, and regulate FDI enterprises to ensure their compliance with national environmental standards. The Vietnamese government also needs to invest further in green technology, develop smart cities, and create sustainable development policies.

REFERENCES

Adebayo, T.S. and Kirikkaleli, D. (2021) 'Impact of renewable energy consumption, globalization, and technological innovation on environmental degradation in Japan: application of wavelet tools', Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, 23(11), pp. 16057–16082.

Ali, Muhammad Uzair et al. (2022) 'CO2 emission, economic development, fossil fuel consumption and population density in India, Pakistan and Bangladesh: A panel investigation', International Journal of Finance & Economics, 27(1), pp. 18–31.

Aluko, O., Opoku, E. and Acheampong, A. (2022) 'Economic complexity and environmental degradation: Evidence from OECD countries', Business Strategy and the Environment [Preprint]. Available at: https://doi.org/10.1002/bse.3269.

Begum, R.A. et al. (2015) 'CO2 emissions, energy consumption, economic and population growth in Malaysia', Renewable and Sustainable Energy Reviews, 41, pp. 594–601. Available at: https://doi.org/10.1016/j.rser.2014.07.205.

Bekun, F.V., Alola, A.A. and Sarkodie, S.A. (2019) 'Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries', The Science of the Total Environment, 657, pp. 1023–1029. Available at: https://doi.org/10.1016/j.scitotenv.2018.12.104.

Bélaïd, F. and Youssef, M. (2017) 'Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria', Energy Policy, 102, pp. 277–287. Available at: https://doi.org/10.1016/j.enpol.2016.12.012.

Bhattacharya, M., Awaworyi Churchill, S. and Paramati, S.R. (2017) 'The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions', Renewable Energy, 111, pp. 157–167. Available at: https://doi.org/10.1016/j.renene.2017.03.102.

Breusch, T.S. and Pagan, A. (1980) 'The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics', The Review of Economic Studies, 47(1), pp. 239–253.

Chandra Voumik, L. and Sultana, T. (2022) 'Impact of urbanization, industrialization, electrification and renewable energy on the environment in BRICS: fresh evidence from novel CS-ARDL model', Heliyon, 8(11), p. e11457. Available at: https://doi.org/10.1016/j.heliyon.2022.e11457.

Cole, M.A., Rayner, A.J. and Bates, J.M. (1997) 'The environmental Kuznets curve: an empirical analysis', Environment and Development Economics, 2(4), pp. 401–416. Available at: https://doi.org/10.1017/S1355770X97000211.

Copeland, B. and Taylor, M.S. (1994) 'North-South Trade and the Environment', The Quarterly Journal of Economics, 109(3), pp. 755–787.

Danish, Ozcan, B. and Ulucak, R. (2021) 'An empirical investigation of nuclear energy consumption and carbon dioxide (CO2) emission in India: Bridging IPAT and EKC hypotheses', Nuclear Engineering and Technology, 53(6), pp. 2056–2065. Available at: https://doi.org/10.1016/j.net.2020.12.008.

Dong, K., Dong, X. and Dong, C. (2019) 'Determinants of the global and regional CO 2 emissions: What causes what and where?', Applied Economics, 51, pp. 5031–5044. Available at: https://doi.org/10.1080/00036846.2019.1606410.

Dong, K., Sun, R. and Dong, X. (2018) 'CO2 emissions, natural gas and renewables, economic growth: Assessing the evidence from China', Science of The Total Environment, 640–641, pp. 293–302. Available at: https://doi.org/10.1016/j.scitotenv.2018.05.322.

Dumitrescu, E.I. and Hurlin, C. (2012) 'Testing for Granger non-causality in heterogeneous panels', Economic Modelling, 29(4), pp. 1450–1460.

Ehrlich, P. and Holdren, J. (1971) 'Impact of Population Growth', Science (New York, N.Y.), 171, pp. 1212–7. Available at: https://doi.org/10.1126/science.171.3977.1212.

Ekins, P. (1997) 'The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence', Environment and Planning A, 29(5), pp. 805–830.

Grossman, G.M. and Krueger, A. (1995) 'Economic Growth and the Environment', The Quarterly Journal of Economics, 110(2), pp. 353–377.

Gygli, S. et al. (2019) 'The KOF Globalisation Index – revisited', The Review of International Organizations, 14(3), pp. 543–574. Available at: https://doi.org/10.1007/s11558-019-09344-2.

Hassan, A. et al. (2024) 'Does nuclear energy mitigate CO2 emissions in the USA?

Testing IPAT and EKC hypotheses using dynamic ARDL simulations approach', Progress in Nuclear Energy, 169, p. 105059. Available at: https://doi.org/10.1016/j.pnucene.2024.105059.

Kalaycı, C. and Hayaloğlu, P. (2019) 'The Impact of Economic Globalization on CO2 Emissions: The Case of NAFTA Countries', International Journal of Energy Economics and Policy, 9, pp. 356–360. Available at: https://doi.org/10.32479/ijeep.7233.

Kim, J., Lim, H. and Jo, H.-H. (2020) 'Do Aging and Low Fertility Reduce Carbon Emissions in Korea? Evidence from IPAT Augmented EKC Analysis', International Journal of Environmental Research and Public Health, 17(8), p. 2972. Available at: https://doi.org/10.3390/ijerph17082972.

Kuznets, S. (1955) 'Economic Growth and Income Inequality', The American Economic Review, 45(1), pp. 1–28.

Le, H.P., Van, D. and Bao, H.H.G. (2018) 'The Role of Globalization on CO2 Emission in Vietnam Incorporating Industrialization, Urbanization, GDP per Capita and Energy Use', International Journal of Energy Economics and Policy, 8, pp. 275–283. Available at: https://doi.org/10.32479/ijeep.7065.

Li, X. et al. (2016) 'The coordination between China's economic growth and environmental emission from the Environmental Kuznets Curve viewpoint', Natural Hazards, 83(1), pp. 233–252. Available at: https://doi.org/10.1007/s11069-016-2314-0.

Majeed, M.T. and Mazhar, M. (2019) 'Environmental degradation and output volatility: A global perspective', Pakistan Journal of Commerce and Social Sciences (PJCSS), 13(1), pp. 180–208.

Maldonado, F. and P. Gallagher, K. (2022) Climate Change and IMF Debt Sustainability Analysis | Global Development Policy Center. Available at: https://www.bu.edu/gdp/2022/02/10/climate-change-and-imf-debt-sustainability-analysis/ (Accessed: 20 September 2024).

Moutinho, V., Varum, C. and Madaleno, M. (2017) 'How economic growth affects emissions? An investigation of the environmental Kuznets curve in Portuguese and Spanish economic activity sectors', Energy Policy, 106, pp. 326–344. Available at: https://doi.org/10.1016/j.enpol.2017.03.069.

Mrabet, Z. and Alsamara, M. (2017) 'Testing the Kuznets Curve hypothesis for Qatar: A comparison between carbon dioxide and ecological footprint', Renewable and Sustainable Energy Reviews, 70, pp. 1366–1375. Available at: https://doi.org/10.1016/j.rser.2016.12.039.

Murshed, M., Ali, S.R. and Banerjee, S. (2021) 'Consumption of liquefied petroleum gas and the EKC hypothesis in South Asia: evidence from cross-sectionally dependent heterogeneous panel data with structural breaks', Energy, Ecology and Environment, 6(4), pp. 353–377. Available at: https://doi.org/10.1007/s40974-020-00185-z.

Ozturk, I. et al. (2024) 'An empirical investigation of financial development and ecological footprint in South Asia: Bridging the EKC and pollution haven hypotheses', Geoscience Frontiers, 15(4), p. 101588. Available at: https://doi.org/10.1016/j.gsf.2023.101588.

Pesaran, M.H., Schuermann, T. and Weiner, S.M. (2004) 'Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model', Journal of Business & Economic Statistics, 22(2), pp. 129–162.

Rehman, A. et al. (2022) 'Sustainable development and pollution: the effects of CO2 emission on population growth, food production, economic development, and energy consumption in Pakistan', Environmental Science and Pollution Research, 29(12), pp. 17319–17330. Available at: https://doi.org/10.1007/s11356-021-16998-2.

Sahir, M.H. and Qureshi, A.H. (2007) 'Specific concerns of Pakistan in the context of energy security issues and geopolitics of the region', Energy Policy, 35(4), pp. 2031–2037. Available at: https://doi.org/10.1016/j.enpol.2006.08.010.

Saud, S. et al. (2019) 'The nexus between financial development, income level, and environment in Central and Eastern European Countries: a perspective on Belt and Road Initiative', Environmental Science and Pollution Research, 26(16), pp. 16053–16075. Available at: https://doi.org/10.1007/s11356-019-05004-5.

Selden, T.M. and Song, D. (1994) 'Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?', Journal of Environmental Economics and Management, 27(2), pp. 147–162. Available at: https://doi.org/10.1006/jeem.1994.1031.

Shafiei, S. and Salim, R.A. (2014) 'Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: A comparative analysis', Energy Policy, 66, pp. 547–556. Available at: https://doi.org/10.1016/j.enpol.2013.10.064.

Shahbaz, M. (2019) ‘Globalization-Emissions Nexus: Testing the EKC hypothesis in Next-11 Countries’, MPRA Paper [Preprint]. Available at: https://ideas.repec.org//p/pra/mprapa/93959.html (Accessed: 30 September 2024).

Shahbaz, M., Shahzad, S.J.H. and Mahalik, M.K. (2018) ‘Is Globalization Detrimental to CO2 Emissions in Japan? New Threshold Analysis’, Environmental Modeling & Assessment, 23(5), pp. 557–568. Available at: https://doi.org/10.1007/s10666-017-9584-0.

WHO (2024) Air pollution. Available at: https://www.who.int/health-topics/air-pollution (Accessed: 20 September 2024).

WMO (2023) State of the Global Climate 2023, World Meteorological Organization. Available at: https://wmo.int/publication-series/state-of-global-climate-2023 (Accessed: 20 September 2024).

World Bank (2020) World Bank Group Climate Change Action Plan 2016-2020, World Bank. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/755721468011421594/World-Bank-Group-Climate-Change-Action-Plan-2016-2020 (Accessed: 20 September 2024).

Xu, B. and Lin, B. (2015) ‘Factors affecting carbon dioxide (CO2) emissions in China’s transport sector: a dynamic nonparametric additive regression model’, Journal of Cleaner Production, 101, pp. 311–322. Available at: https://doi.org/10.1016/j.jclepro.2015.03.088.

Xu, B. and Lin, B. (2017) ‘Factors affecting CO2 emissions in China’s agriculture sector: Evidence from geographically weighted regression model’, Energy Policy, 104, pp. 404–414. Available at: https://doi.org/10.1016/j.enpol.2017.02.011.

Yang, X. et al. (2022) ‘The impact of renewable energy consumption, trade openness, CO2 emissions, income inequality, on economic growth’, Energy Strategy Reviews, 44, p. 101003. Available at: https://doi.org/10.1016/j.esr.2022.101003.

Yandle, B., Bhattarai, M. and Vijayaraghavan, M. (2004) ‘Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications’, PERC, 2.

Zaba, B. and Clarke, J.I., 1994. Introduction: current directions in population-environment research. Environment and population change, pp.9-43.