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The Role of Renewable Energy on the Environmental Degradation: Evidence from ASEAN Countries

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ABSTRACT

Environmental degradation (ED) is now a global problem because of expanded economic activities. This issue demands the academics' and policymakers' intentions. Hence, the paper conducts an investigation the impact of renewable energy (RE) output, consumption, and energy import (EI) on the carbon dioxide (CO2) emissions in ASEAN region. The secondary data was collected using World Development Indicators (WDI) for 2008-2021. The research also investigates the association between the variables using the Methods of Moments-Quantile-Regression (MMQR) approach. The outcomes indicated the RE output, consumption, EI, EG, and population growth on the CO2 emissions in ASEAN economies. The paper gives directions to the policymakers while forming policies related to reduce CO2 emissions using RE production.

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1. Introduction

An environment always influences the economic development of a country, including social prosperity and individuals' well-being. The environment quality affects the health of humans and other living resources which humans use. In a preserved, clean environment, humans may live a healthy, pleasant, and active life. The healthy living resources and high-quality physical natural resources in abundance quality from the environment not only serve the satisfaction of present needs but also add to the success in achieving sustainable development goals (Altıntaş & Kassouri, 2020). Several contaminating factors come into existence by nature, or sometimes there is a human role in it because of their social and economic activities. These factors spoil the natural resources' efficiency and the speed of the country's development. CO2 emission is one of these contaminating causing ED. CO2, while crossing a balanced volume, traps heat into the earth, causes global warming, and creates a disturbance in the natural cycle of climate. These may have negative repercussions for living natural bodies, humans, and the environment, along with their productivity (Huang, Ahmad, & Ali, 2022). Consequently, jeopardy arises for the country's thorough development, which requires a pleasant and comfortable environment and productive environment elements like air, water, soil, minerals, bio-productive resources,

and human resources. Thus, CO2 emissions should be controlled to overcome ED and associated risks (Rahman, 2020).

Some factors like RE output and consumption, and EI have their role in mitigating CO2 emissions and reducing ED. RE is a sustainable energy technology as it is generated by using renewable natural resources, and it has the nature of being replenished automatically or with some effort. The production of RE includes the growth of plants and greenery, absorption of heat, light, and harmful gases from the air, purity of soil & water, and mitigation of wastes. So, it reduces CO2 existing in the air and preserves the environment from getting degraded (Nasir, Canh, & Le, 2021). The encouragement of RE consumption could bring a remarkable fall in demand for fossil fuels and nuclear reactions to generate energy. So, the expected CO2 emission from human practices because of fossil fuels and nuclear reactions is controlled, and the natural environment is safe. EI includes the procurement of energy and the resources required for energy production from foreign suppliers. The import of clean and affordable energy technologies helps overcome unclean energy consumption. As a result, the CO2 emissions control preserves the environment from getting degraded (Chien, 2022).

The study examines the ED in ASEAN countries. This energy mix contributes to the low-cost vision, produces electricity, and achieves socioeconomic development (Nathaniel, 2021). But to the dark side, this energy mix has tended the energy production units and energy-consuming firms to be the largest CO2 emitter. Therefore, it is the largest one contributing to ED and creating issues for humans. Because of the lacking government and private initiatives for de-carbonization in the economy, CO2 emission, particularly from energy use, is anticipated to double by 2040, reaching up to 2.3 billion tons (Burki & Tahir, 2022). This ED jeopardizes the region's socioeconomic development, having destroyed its work environment, degrading human resources' efficiency and spoiling the quality of natural resources. In this situation, researchers should turn the attention of people and authoritative entities to reduce CO2 emissions. The current article aims to explore the role of renewable energy like RE output and consumption, and EI in mitigating ED through reducing CO2 emissions.

This study broadens the scope of the literature. First, there is ample literature on RE's contribution to the mitigation of ED. But very few studies have discussed both RE output and consumption separately for environmental preservation in clear detail. The present article fills the gap and discusses the role of RE output and consumption, along with EI, in mitigating ED. Second, the authors have written about ED and used different proxies to measure it. The current study takes CO2 emissions as a predictor of ED and, thus, contributes to the literature. Third, the present article makes an exceptional contribution to the literature with the analysis of the role of RE output, RE consumption, and EI in mitigating ED for ASEAN economies.

The current study has several parts: The second part is the review of the literature on the relationship among factors. The third part describes research methods followed by results extraction. The results are showed explained and supported by previous studies. It describes the research in short, shows its implications with detail and limitations.

2. Literature Review

The environment quality determines the natural resources and human capital available to the country. The availability of physical, human, and living resources, which serves as a source to raw materials and other economic resources, determines the country's ability to make economic progress. There is a destructive threat to the environment because of population growth, machinery and energy use, and many economic practices that all cause CO2 emissions But humans transition to RE with the management of some other factors eradicating CO2 emissions and preserving the environment and its resources from degradation (Anwar, Siddique, Dogan, & Sharif, 2021). The current research article addresses the RE output and consumption, EI, EG, and population role in mitigating

ED. Different authors have analyzed the nexus among the RE output and consumption, EI, EG, population, and ED. The current study checks the relationship among these factors by analyzing the views from previous studies.

RE, like wind energy, bio-fuel, biomass, hydropower, solar energy, and geothermal power, etc., is produced from natural resources, environmental elements, and wastes from houses, agriculture, and factories. It itself leaves no waste, mitigates wastes, and absorbs carbon. So, the increasing RE output reduces waste and CO2 emissions. It results in the mitigation of ED (Cheng, Ren, Wang, & Yan, 2019). Doğan, Driha, Balsalobre Lorente, and Shahzad (2021), checks how RE output mitigates ED. Authors struggled to collect annual panel data from 28 OECD states spanning the time from 1990 to 2014. The research focuses on the point that the fossil fuels combustion emits carbon and causes CO2 emissions into the air. Increasing RE output provides an alternative to fossil fuels and a solution to ED with lower CO2 emissions. Magazzino, Mele, and Schneider (2021), investigates the role of RE technologies like wind and solar energy output and coal-based energy output in ED. The article explains that the increase in the RE output from wind turbines and solar panels provides an eco-friendly energy supply in comparison to coal-producing energy. Consequently, the energy consumption is neutral to CO2 emissions, and the environment is less likely to degrade.

RE is a form of fuel that is attained from natural resources and procedures. When this type of energy is utilized for infrastructure, logistics, mechanical, and procedural functions, it neither releases toxic gaseous particles nor causes wastes containing chemicals or bacteria. So, RE consumption is a way to eradicate CO2 emissions and not let the environment degrades (Agyekum, Amjad, Mohsin, & Ansah, 2021). Younis, Naz, Shah, Nadeem, and Longsheng (2021), identifies the relationship between RE consumption, stock performance, urbanization, and ED. The panel data of BRICS spanning 1993-2018 was analyzed through the GMM estimation in order to assess the association between selected variables. Authors have the view that firms' tendency to consume RE fuel as an alternative to energy from minerals like coal, oil, and gas, etc., reduces CO2 emission while domestic and commercial activities are being performed, and there is a fast decrease in ED. Sharif, Raza, Ozturk, and Afshan (2019), attempted research on the role of RE consumption and ED by comparing it with the situation when NRE is in use. The data from 74 countries during 1990-2015 was analyzed. The results showed a negative role of RE consumption in ED because increasing RE consumption reduces CO2 volume from the atmosphere.

EI is a trade policy allowing the domestic people to procure energy or technologies associated with energy production or consumption whenever needed. The facility to import eco-friendly energy and produce eco-friendly energy having technologies from foreigners discourages the use of fossil fuels and perform nuclear reaction to generate energy. It results in a remarketing decrease in CO2 emissions and protects the natural environment (Sharif et al., 2020). Alola, Bekun, and Sarkodie (2019), integrates the relationship of EI with the mitigation of ED. The study implies that the nature of the EI affects the role of EI in mitigating ED. The purchase of fossil fuels from foreign sources spoils the environment increasing CO2 emissions. Whereas, if the policy is to import clean energy through grids, pipes, or storage systems, the total fossil fuels consumption decreases, bringing a fall in CO2 emissions and protecting the productivity of environmental elements. Adewuyi and Awodumi (2021), investigates the association of EI, economic progress, and ED. The data from Nigeria and South Africa from the time of 1981-2015 by SEM and threshold regression analysis. The study implies that the import of petroleum commodities overcomes CO2 emissions from domestic and economic practices below a threshold value.

EG determines technological development, improves the processes for human capital development, and gives rise to sharing of information and strategies. In this situation, though economic practices are usually the source of pollution, many economic actors are able to assess and maintain the quality of the environment with the responsible use of natural and environmental resources. Thus, EG provides the potential for people to mitigate CO2 and ED (Ozcan, Tzeremes, & Tzeremes, 2020). In a research article, Adedoyin,

Gumede, Bekun, Etokakpan, and Balsalobre-Lorente (2020), talks about the role of EG and coal rents CO2 mitigation representing environmental quality in the presence of energy and environment-related regulations. The economy, energy, regulations, and CO2-related data were collected from a sample of BRICS economies for the period of 1990-2014. The results from the assessment through PMG-ARDL indicated a significant relationship between EG and ED. When a country continues to grow economically, it can start green energy production programs and campaigns for creating eco-awareness. This leads to success in eradicating CO2 emissions and raising the quality level. Mikayilov, Galeotti, and Hasanov (2018), explores the EG impact on ED. The results show that EG improves financial development and green financing encourages actions against CO2 and ED.

The population of a region is commonly taken as a natural source of CO2 emissions and as a cause of the deteriorating quality and functioning of the environment. But it is admissible that population determines the human capital, the technological and physical infrastructure, education, regulations, and economic development. The regions with rich populations are the center of focus and enjoy different types of reformation. These regions have potential control over environmental issues like CO2 emission and lack of quality of air, water, soil, and climate. Thus, population growth and ED are negatively associated with (Ilham, 2021). Wang and Dong (2019), also examines the impacts of population growth on sustainable energy technologies and environmental quality. The study implies that the regulators who are responsible for managing the geographical characteristics and developing infrastructure are more attentive to the development of the populous country. If the population growth rate is increasing in a region, the geographical features are reformed, and improved technical & physical infrastructure facilities are provided to people. In these circumstances, technologies that can overcome CO2 emissions can be promoted, and there is mitigation of ED.

3. Research Methods

The research analysis the impact of RE output, consumption, EI, EG, and population growth on the CO2 emissions in ASEAN countries. The secondary data was collected from WDI from 2008 to 2021. The article developed the equation given below:

$$CO2E_{it} = \alpha_0 + \beta_1 REO_{it} + \beta_2 REC_{it} + \beta_3 EI_{it} + \beta_4 EG_{it} + \beta_5 PG_{it} + e_{it} \quad (1)$$

Where;
CO2E = Carbon Dioxide Emissions
t = Time Period
i = Countries
REO = Renewable Energy Output
REC = Renewable Energy Consumption
EI = Energy Import
EG = Economic Growth
PG = Population Growth

The research used ED as the main variable measured with CO2 emissions (metric tons per capita). Moreover, the research also used three predictors such as RE output proxies as RE output (% of total), RE consumption proxies as RE consumption (% of total), and EI proxies as EI (% of energy use). In addition, the research also used EG and population growth as control variables to predict CO2 emissions.

The study checks the variables' details using descriptive statistics. In addition, the study also checks the correlation using a correlation matrix. Moreover, the study also checks the multicollinearity using the variance inflation factor (VIF). The equations for the approach are mentioned below:

$$R^2_Y \longrightarrow Y_{it} = \alpha_0 + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + e_{it} \quad (2)$$

$$j = R_Y^2, R_{X1}^2, R_{X2,}^2 R_{X3,}^2 R_{X4,}^2 R_{X5}^2 \quad (3)$$

$$Tolrance = 1 - R_j^2 \qquad VIF = \frac{1}{Tolerance} \quad (4)$$

The research also investigates the association between the variables applying the MMQR methods. This is a newly established approach introduced by Machado and Silva (2019). It is the best approach for panel data because it has the robust outliers feature (Adebayo et al., 2022). The conditional quantile is established as under:

$$Y_{it} = \alpha_i + X_{it}\beta + (\delta_i + Z_{it}\lambda)U_{it} \quad (5)$$

In this equation, $P\{\delta_i + Z_{it}\lambda > 0\} = 1$ exposed the probability, while $\alpha, \beta, \lambda \, and \, \delta$ exposed the parameters that necessitate being assessed. Moreover, the components are transformed with component l mentioned below:

$$Zl = Zl\,(X), l = 1, \ldots\ldots, k \quad (6)$$

In this equation, U_{it} exposed the orthogonal to X_{it} and reliable with attaining the moment conditions that do not contain stringent heterogeneity. So, in equation (5), the conditional quantile of Y is expressed as below:

$$Q\tau(\tau/X_{it}) = (\alpha_i + \delta_i q(\tau)) + X_{it}\beta + Z_{it}\,\lambda\, q(\tau) \quad (7)$$

In this equation, X_{it} exposed the independent variables, for example, REO, REC, EI, EG, and PG and Y_{it} represents the dependent variable, for example, CO2E, that is conditional as X_{it}. SO, $Q(\tau)$ is expressed as under:

$$Min_q = \sum_t \sum_i p\tau\,(R_{it} - (\delta_i + Z_{it}\,\lambda\,)q) \quad (8)$$

4. Research Findings

The research examines the variables' details using descriptive statistics. The outcomes indicated that the CO2E average figure was 4.437, REO mean figure was 31.182 percent, and REC average figure was 30.290 percent. In addition, the outcomes also indicated that the EI average figure was -25.585 percent, EG figure value was 4.329 percent, and PG figure value was 1.180 percent. These figures are mentioned in Table 1.

Table 1
Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
CO2E	140	4.437	5.065	0.153	20.569
REO	140	31.182	32.433	0.033	114.241
REC	140	30.290	24.909	0.005	85.710
EI	140	-25.585	129.416	-522.429	129.691
EG	140	4.329	4.045	-17.913	14.520
PG	140	1.180	0.742	-4.170	5.322

In addition, the study also checks the correlation using a correlation matrix. The outcomes indicated the RE output, RE consumption, EI, EG, and population growth on the CO2 emissions in ASEAN countries. These figures are mentioned in Table 2.

Moreover, the study also checks the multicollinearity using VIF. The outcomes revealed that the values are lower than five while the reciprocal is larger than 0.20. These outcomes indicated no multicollinearity issue. These figures are mentioned in Table 3.

The research also investigates the association between the variables using the MMQR approach. The outcomes indicated the RE output and consumption, EI, EG, and

population growth on the CO2 emissions in ASEAN countries. These figures are mentioned in Table 4.

Table 2
Matrix of Correlations

Variables	CO2E	REO	REC	EI	EG	PG
CO2E	1.000					
REO	-0.559	1.000				
REC	-0.751	0.764	1.000			
EI	-0.661	0.253	0.259	1.000		
EG	-0.403	0.331	0.395	0.262	1.000	
PG	-0.009	0.028	-0.038	0.007	0.038	1.000

Table 3
Variance Inflation Factor

	VIF	1/VIF
REC	2.581	0.387
REO	2.446	0.409
EG	1.230	0.813
EI	1.115	0.897
PG	1.012	0.988
Mean VIF	1.677	.

Table 4
Panel Quartile Estimation (MMQR)

Variables	Method of Moments Quantile Regression (MMQR)										
	Location	Scale	Grid of Quartiles								
			0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
REC	0.546***	0.657*	0.657**	0.758**	0.647*	0.647**	0.775*	0.092	0.763*	0.903**	0.175*
REO	0.657**	0.545*	0.102**	0.433*	0.393*	0.784***	0.078	0.874**	0.748**	0.028	0.133*
EI	0.756***	0.493**	0.647**	0.049**	0.674*	0.019	0.643*	0.202**	0.191*	0.433**	0.091
EG	0.859**	0.403**	0.342*	0.393**	0.203**	0.011	0.647**	0.564**	0.784**	0.009	0.543*
PG	0.483*	0.493**	0.327*	0.102**	0.783***	0.931*	0.718*	0.029	0.564*	0.498*	0.549*

5. Discussions

The results demonstrated that RE output has a negative relationship with ED. These results agree with Olabi and Abdelkareem (2022), which highlights that the increasing RE production on the part of government energy sectors and private entities personally reduce the CO2 emissions by cleaning the air or reducing the use of mineral products like coal, ore, oil, gas, etc. So, RE output overcomes ED. These results align with Zhou, Jia, Altuntaş, Kirikkaleli, and Hussain (2022), which checks how much helpful RE output is in controlling ED. The study implies that the increasing RE output makes the individuals and firms management intend to utilize fossil fuels in less amount and controls CO2. Thus, the environment is safe from destruction.

The findings demonstrated that RE consumption has a negative relationship with ED. These results agree with Akam, Owolabi, and Nathaniel (2021), which claims that the economy, with the firms turning to rely on RE consumption, reduces the fossil fuel consumption causing CO2 emissions and reducing ED. These results align with Elavarasan et al. (2020), which proclaims that the intention to consume RE forces firms to employ eco-friendly technologies which need low voltage power and release less amount of carbon-containing particles. The reduction in CO2 emissions leads to environmental protection.

The results indicated that EI has a negative relationship with ED. These results are supported by Levenda, Behrsin, and Disano (2021), which claims that the import of energy production technologies, the resources or materials used in energy production, and the purchase of energy itself enables the country to start the replacement of fossil fuels with a clean energy source. It ensures environmental preservation against CO2 emissions. These results align with Hou et al. (2019), which implies that the import of clean energy stabilizes the supply of clean energy and prices of energy within the country. This encourages sustainable energy consumption and saves the earth from CO2 emissions.

The outcomes demonstrated that EG has a negative relationship with ED. These results match with Muhammad, Khan, Khan, and Khan (2021), which implies that the rise in the EG rate makes the government develop a crew responsible for watching environmental conditions and control over CO2 emissions. This all preserves the environment. These results align with Shafique, Azam, Rafiq, and Luo (2021), which also highlights that while an economy is achieving a higher EG rate, it is in a better position to work on environmentally-friendly projects and brings a fall in ED with the least CO2 emissions.

The results revealed that population growth is negatively linked ED. These results agree with Azam, Uddin, and Saqib (2023); if the population growth rate is getting higher, the government itself carries human capital development programs. When there is efficient human capital available in the economy, work can be started on environmentally friendly projects, and success is sure in achieving the goal of a clean environment. These findings align with Maja and Ayano (2021). The study states that if the population is larger in number, there is the performance of infrastructure building practices. Thus, there is a way to control CO2 and reduce ED.

6. Conclusion

The research objective was to examine the role of RE output, consumption, and EI in mitigating ED. The aim of the study was also to analyze the role of EG and population growth in mitigating ED. The quantitative data for RE output, RE consumption, EI, EG, population growth, and CO2 emissions were collected from ASEAN countries. The results showed a negative association between RE output, RE consumption, EI, EG, population growth, and ED. The results showed that the increasing RE output triggers sustainable energy supplies and discourages people from utilizing fossil fuels to undertake functions and hit goals. The decreasing CO2 saves the environment from degradation. Likewise, the ability to consume RE emphasizes eco-friendly technologies, reduce fossil fuels, and mitigate waste emission. The reduction in CO2 emissions leads to environmental protection. The research findings showed that the country engaged in the import of energy could supply renewable clean energy for the economy and prevent it from releasing CO2 emissions. As a result, the environment is clean. The results also showed that population growth is a key to areas' development and capability to run eco-friendly initiatives. So, saves the economy from degradation. EG improves affordability to adopt eco-friendly economic practices, and therefore, the environment is not likely to degrade.

6.1 Implications

Research may learn from the current study as it contributes to the literature. The study sheds light on the role of RE output, RE consumption, and EI, along with population growth and EG, in mitigating ED. In addition, the researchers may learn about the role of RE output, consumption, EI, EG, population growth, and CO2 emissions with respect to ASEAN economies.

The current article has great significance to emerging economies like ASEAN countries where CO2 emissions and its repercussion affect environmental productivity. The study provides guidelines to country regulators on how to prevent the environment from degrading. The study guides that policies should be made to enhance RE output in order to mitigate ED with minimal CO2 emissions. The study also provides a guideline that firms must be motivated for RE consumption, and thereby, the environment must be preserved. The study also suggests that trade policies should be designed to encourage EI to avoid ED. The research provides guidelines to the policymakers in making policies related to reduce CO2 emissions using RE production. There is also a recommendation that effective strategies must be formed to accelerate and sustain EG. It would refrain the economy from emitting CO2 emissions, and there would be a fall in ED. Moreover, the study conveys that government must manage population growth to develop the country, and thus, CO2 emissions should be controlled.

6.2 Limitations

The current study also has some limitations, and future research must have better grounds to be applicable. The present article only examines the influences of RE output, RE consumption, EI, EG, and population growth on mitigating ED. There are numerous variables like environmental taxes, green finance, corporate governance, etc. which may affect environmental quality. Future researchers must also examine these factors. Moreover, the evidential data were collected from only ASEAN economies that have specific environmental characteristics, environmental conditions, and economic value. Authors must look at the statistics of multiple countries to attain applicable results.

Authors Contribution

Sajjad Hussain: study design, critical revision, incorporation of intellectual content, drafting
Waseem Yousaf: data collection, data analysis, data interpretation, drafting

Conflict of Interests/Disclosures

The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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