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Probing the Nexus Effect of CO2 Emissions, Fossil Fuels, Energy Imports, and Economic Growth on Renewable Energy Consumption in OIC Member Countries in Southeast Asia: Evidence from Panel Data Estimations

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ABSTRACT

In recent years, the role of renewable energy sources has increased in the amount of energy consumed worldwide. Much remains unknown about the components that influence renewable energy consumption. This article addresses this issue for the Southeast Asian countries that are members of the Organization of Islamic Cooperation (OIC): Indonesia, Malaysia and Brunei Darussalam. Besides having major energy resources, the region is well suited for renewable energy development as it can measure the effects of carbon dioxide emissions, fossil fuels, energy imports, and economic growth. In this study, we found that there is no statistically significant difference in renewable energy consumption in previous years; economic growth and concurrent increases in carbon dioxide and fossil fuel emissions do not have a positive impact on renewable energy use in the OIC region of Southeast Asia; and the impact of energy imports has a significant impact on the consumption of renewable energy. In addition, how the findings of this study impact policy is discussed.

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1. INTRODUCTION

Energy is an important part of nature-human interaction and economic development, but exergy is the maximum potential that can be obtained from the work of an energy stream or energy in a reference environment. [1]. Energy scarcity, climate change and global warming have driven government policies to support a low-carbon economy and improve energy efficiency. It is expected that increased energy efficiency will reduce energy use. Costs for consumers, fossil fuel imports, and CO2 emissions. As a result, renewable energy (RE) is becoming an increasingly important alternative energy source [2]. Concerns over fossil fuel consumption continue to rise due to the negative environmental impact of global

warming and greenhouse gas emissions. Therefore, renewable energy is now a vital component of global energy consumption. Renewable energy offers many important benefits, especially in reducing carbon dioxide emissions and protecting the environment. While fossil fuels are theoretically considered renewable in the long term, it is important to understand that renewable energy is a reliable and sustainable source of energy for the future. Understanding the key determinants of renewable energy and drawing implications from these results is crucial for energy policy. [3].

The United Nations (UN) designated the 2014-2024 decade as the Decade of Sustainable Energy for All [4]. Sustainability in energy use will result in a cleaner environment, greater access to electricity, improved energy efficiency with lower-carbon renewable energy, and increased investment in cleaner technologies. Renewable energy use is increasing globally, helping to tackle climate change and provide greater energy access for billions of people still living in poverty. Renewable energy is estimated to have accounted for 19.1% of final energy consumption worldwide in 2013 [5]. According to the International Energy [6], we estimate an increase in renewable energy use, such as global power generation, from 2022 to 2050 of 30% to 76%, depending on the situation, and most of it will be met by zero-carbon technologies. As such, we estimate that 81% to 95% of the new power generation capacity installed from 2022 to 2050 will be global power generation.

The OIC group consists of 57 countries, making it the largest group outside of the UN. Its member states have a total population of more than 1.80 billion, or nearly 24 percent of 7.55 billion people worldwide. This study will use OIC members in Southeast Asia. Of the twenty-one countries in the Sub-Saharan Africa Group, eighteen are in the Middle East and North Africa, nine in Europe and Central Asia, four in South Asia, three in Southeast Asia, and two in Latin America. Indonesia, Malaysia and Brunei Darussalam are very different from each other in terms of geography, climatic conditions, economic and human development, and key energy resources. They are also undergoing major socio-economic transitions, for which energy and electricity will be critical. [7].

The aim of this research is to examine the relationship between carbon dioxide emissions, fossil fuels, energy imports and economic growth on the use of renewable energy in Southeast Asian countries as members of the Organization of Islamic Cooperation (OIC) from 2000 to 2020. With a regression model. Fixed effects (CEM), traditional assumption tests were also used. Previous research concentrated on the causal relationship between renewable energy consumption and four independent factors. OIC member countries in Southeast Asia have not made this relationship the subject of investigation. The structure of this paper is as follows: Section 2 presents a literature review on the relationship between renewable energy use, economic growth, carbon dioxide, fossil fuels, and energy imports; Section 3 describes the data, techniques, and results from national and multinational studies; and Section 4 concludes the research results.

Using a quantitative panel approach, this study aims to find out how CO2 emission, fossil fuels, energy imports, and economic growth affect renewable energy use in Organization of Energy Cooperation (OIC) member countries in Southeast Asia from 2000 to 2020. Effects regression model (CEM) combined with classical assumption tests. This study extends previous research, especially regarding the causal relationship between the four independent variables and renewable energy consumption. No study has investigated this relationship in Southeast Asian OIC member countries. The rest of the paper is organized as follows: Section 2 presents previous literature on the relationship between CO2, fossil fuels, energy imports, and economic growth to renewable energy use; Section 3 presents data, methods, and results from country-specific and multi-country studies. Section 4 concludes.

2. LITERATURE REVIEW

Globally, the utilization of renewable energy has surged. At first, conventional non-renewable energy sources including coal, diesel, and gasoline were used to produce energy. But in order to attain sustainable energy growth, both developed and emerging nations are now focusing on integrating renewable energy sources including biomass, geothermal, wind, and solar power [8].

2.1 The CO2 Emission on Renewable Energy

Since the 1990s, C02 emissions from energy use in newly industrialized countries have increased significantly. Increasing global warming and climate change issues, environmental degradation has reached a critical point. As a result, in recent years, it has become important to understand the factors that cause environmental degradation as well as their relationship with renewable energy development [9].

2.2 Fossil fuels on Renewable Energy

The energy systems of both developed and developing countries rely on fossil fuels. Many studies have addressed the problems associated with their use. It is responsible for environmental issues such as global warming and air pollution, and also has adverse social impacts related to people's health and quality of life. Energy systems are becoming unsustainable due to all these issues, and new solutions are being sought to reduce their negative effects [10]. Around the world, it is clear that achieving a sustainable energy system is still difficult. New policies and mechanisms such as feed-in tariffs have been used to encourage renewable energy. To address the issues posed by the transition to a low-carbon energy system, demand-side strategies and smart grids have also been discussed [11].

2.3 Energy imports on Renewable energy

Self-reliance in energy supply security is further strengthened by the increasing demand for energy [12]. Studies show that, although the energy sector is evolving towards sustainable economic growth and sustainability, the dominance of non-renewable energy imports in developing countries leads to high energy production costs. Instead, energy imports have replaced advanced renewable energy production techniques such as photovoltaic (PV) technology and efficient techniques for wind and hydropower [13]. Renewable energy sources help create more energy and maintain security of supply in the event of disruptions or interruptions [14]. Renewable resources will make economies more resilient to price fluctuations and uncertainties in fossil fuel markets around the world. Renewable resources will also protect the country's economy from the impact of future fossil fuel shortages as well as from military and geopolitical conflicts that often occur in fossil fuel-rich countries. [15].

2.4 Economics growth on Renewable energy

Due to increased energy use, the environment is becoming more polluted as the economies of developing countries expand. Rising environmental costs will also halt economic progress. Due to environmental reasons, the use of renewable energy sources is recommended. To meet energy needs, it is essential to use sustainable and renewable resources. Due to economic growth and increase in population, production and consumption activities increase, resulting in environmental pollution and destruction of natural resources. The environmental costs caused by pollution affect the economic budget, so using renewable energy is a solution [16].

3. METHODS

The impacts of CO2 emissions, fossil fuel imports, energy imports, and economic growth on the use of renewable energy in OIC Southeast Asian member nations are investigated quantitatively in this article. Three OIC Southeast Asian member nations are included in the population sample that was employed between 2000 and 2020. These nations are Brunei Darussalam, Malaysia, and Indonesia. The World Bank database provided the information for all variables and nations.

Using panel regression between the Fixed Effect Model, Random Effect Model, and Common Effect Model, this research

creates a model that examines the effects of CO2 emissions, fossil fuel imports, energy imports, and economic growth on the development of renewable energy. It can be applied to the data processing of this research after taking the Random Common Effect Model into account. Panel data regression is used for data analysis. Gujarati [17], claims that panel data regression integrates cross-sectional and time-series data, yielding more observations and a more thorough analysis than cross-sectional and time-series data alone. A fixed effects model, which can be expressed as follows, was applied:

Where:

$$RNWit = a + \beta 1CO2it + \beta 2ENRit + \beta 3FOSit + \beta 4ECOit + \varepsilon it$$

RNW : Renewable energy consumption (%)
CO2 : CO2 emissions (kt)
ENR : Energy imports, net (%)
FOS : Fossil fuel energy consumption (%)
ECO : Economic Growth (%)
α : The Constant
ε : Term error

Table 1. Description of variables

Variables	Abbreviations	Measurements	Sources
Renewable Energy	RNW	Renewable energy consumption (% of total final energy consumption	WBD
CO2 Emissions	CO2	CO2 emissions (kt)	WBD
Fossil Fuels	FOS	Fossil fuel energy consumption (% of total)	WBD
Imported Energy	ENR	Energy imports, net (% of energy use)	WBD
Economic Growth	ECO	Economic Growth (%)	WBD

* World Bank Data (2023).

4. RESULTS AND DISCUSSION

After defining the model with the selected variables (see Table 1), all data were left in their original form without converting them to logarithms. Table 2 displays descriptive statistics for the variables used. The results of the correlation matrix show that all correlations

Table 2. Descriptive Statistics

	RNW	CO2	ENR	FOS	ECO
Mean	12,117	208.16	-251.36	86,787	3.4579
Median	3.1750	20113	-74,247	96,422	4.7370
Maximum	44,660	60529	-5.5050	100.00	8.8588
Minimum	0.0000	4620.1	-859.55	60,591	-5.4568
Std. Dev	15,840	18374	3.0276	16,251	16,251
Skewness	0.9697	0.4381	-0.9610	-0.7288	-0.9610
Kurtosis	2.2533	2.0374	3.0934	1.6113	3.0934
Observations	62	62	62	62	62

Source: author's own calculation

Table the five variables, including dependent and independent variables, have descriptive statistical results shown in Table 2. The level of renewable energy use in the three Southeast Asian OIC member countries is quite high, with a standard deviation of 15.84 and a minimum value of 0.00 and a maximum value of 44.66 from 2000 to 2020. The average value of renewable energy development is 12.11. Redundant, Hausman, and Lagrange Multiplier test analyses were conducted to determine the selected panel regression model, and the results are as follows:

Table 3. Redundant Fixed Test

Effect test	Statistics	df	Prob.
Cross-section F	3.197621	(2.55)	0.0486**
Chi-square cross-section	6.819947	2	0.0330**

1. **means reject null hypothesis alpha 5% of significant level
2. The null hypothesis is Common Effect Model CEM

3. The alternative hypothesis Fixed Effect Model FEM

Table 4. Hausman Test

Test Summary	Chi-Sq Statistics	Chi-Sq df	Prob.
Random cross-section	2.806008	4	0.5908**

1. **means reject null hypothesis alpha 5% of significant level
2. The null hypothesis is Fixed Effect Model FEM
3. The alternative hypothesis Random Effect Model FEM

Table 5. Lagrange Multiplier test

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	0.504304	7.806475	8.310778
	(0.4776)**	(0.0052)	(0.0039)
Honda	-0.710143	-2.794007	-2.477808
	(0.7612)	(0.9974)	(0.9934)
King-Wu	-0.710143	-2.794007	-1.519520
	(0.7612)	(0.9974)	(0.9357)
Standardized Honda	2.353168	-2.730619	-7.451589
	(0.0093)	(0.9968)	(1.0000)
Standardized King-Wu	2.353168	-2.730619	-8.310282
	(0.0093)	(0.9968_	(1.0000)
Gourieroux, et al.	--	--	0.000000
			(1.0000)

1. **means reject null hypothesis alpha 5% of significant level
2. The null hypothesis is Random Effect Model FEM
3. The alternative hypothesis Common Effect Model CEM

The authors used the redundancy test to determine the best model between the fixed effects model and the random effects model, with the null hypothesis being the fixed effects model. The redundancy test results above show that the probability value is 0.0330 <0.05, rejecting the null hypothesis or fixed effects model and supporting the fixed effects model. After that, the authors used the Hausman test to determine the best model between the fixed effects model and the random effects model, with the null hypothesis being the random effects model. The Hausman test results show that the probability value is 0.5908 > 0.05. This rejects the null hypothesis or fixed effect model and accepts the Random Effect Model.

Using the null hypothesis for the random effects model, the authors then performed a Lagrange Multiplier test to ascertain which model best fits the data between the random effects model and the general effects model. According to the test results, the common effect model is accepted and the fixed effect model is rejected when the probability value is 0.4776 > 0.05. As a result, the general effects model was employed in this investigation, and if it is approved, the study will yield fruitful outcomes. The findings of the traditional assumption tests—autocorrelation, heteroscedasticity, and multicollinearity—indicate that there are no issues with the processed data. The multicollinearity assumption for the four variables is met because the multicollinearity test results for the C02, ENG, FOS, and ECO variables demonstrate that they are below 10.00. The Obs* R-squared value in the heteroscedasticity test findings is 0.2132 (> 0.05), indicating that the data is successful. Furthermore, N = 21 data points are shown by the Durbin Watson autocorrelation test, and K (independent variables) contains 4 variables. These outcomes are derived from the Durbin Watson reference table with a = 5%: DW (Durbin Watson) value 2.181820, DU value 1.8116, 4-DU value 2.1884, 4-DL value 3.0728, and DL value 0.9272. Consequently, this study used a joint effect model based on the Durbin Watson autocorrelation test results, which are DU = DW =. Table 5 displays the model's estimation results.

Table 6. Common Effect Model Results

Variables	Coefficient	Std error	t-statistic	Sig.
C	132.8339	5.030654	26.40490	0,000
C02	-4.13-05	4.85-06	-8.521846	0.000***

ENG	0.009657	0.001897	5.091622	0.0000***
FOS	-1.2635336	0.044449	-28.42694	0.0000***
ECO	-0.008567	0.131891	-0.064953	0.9484
R2	0.974	F-Statistics	541.7788	
Adj R2	0.972	Prob(F-statistic)	0,000**	

*, **, *** represent 1%, 5%, 10% significance level, respectively.

The long-term parameter estimates for the independent variables are displayed in Table 6. The findings demonstrate that the F-statistic's probability value is 0.000 <0.05, meaning that all independent factors have an equal impact on the dependent variable.

Changeable With an adjusted-R square (adj-R2) value of 0.972, all independent variables account for 97.2% of the variation in the dependent variable. The remaining 2.8% can be explained by other factors that were not examined in this study. Every variable's significance is indicated by its sign value. Table 5 indicates that ENG, FOS, and ECO had substantial levels of 10%, 9%, and 10%, respectively, of CO2 and FOS. Since ECO's probability value is higher than alpha, the outcome is not statistically significant.

4.1. The CO2 Emission on Renewable Energy

According to our research, the CO2 coefficient is negative (-4.13), which implies that if CO2 emissions rise by 1%, renewable energy use will fall by 4.13%, providing all other variables remain constant. This is consistent with the IEA (2011) [18] statement that the primary non-renewable energy sources are coal, petroleum, and natural gas. Because of the greenhouse gas (GHG) impact, carbon dioxide (CO2) emissions into the atmosphere are rising as a result, and this is thought to be a significant cause of environmental harm. Because of this, the usage of renewable energy has been inconsistent due to societal and political constraints brought about by climate change and the growing threat of global warming [19]. While there is no causal relationship between renewable energy consumption and CO2 emissions, there is a unidirectional causal relationship from 1960 to 2007.

4.2. Energy imports on Renewable energy

Our study found that the coefficient of ENG has a positive value of 0.009, which means that holding other variables constant, if ENG increases by 1%, the level of renewable energy use will increase by 0.009%. This supports the research of Kilinc-Ata, N [20], Studies conducted during the period 1990-2008 examined how energy imports led to an increase in renewable energy consumption in several countries in the United States and the European Union. The results show that effective import policies, such as tax incentives, feed in tariffs, and tenders, increase renewable energy consumption and have a positive effect.

4.3. Fossil fuel on Renewable energy

The coefficient of FOS in this study is negative -1.263, which indicates that, assuming other variables remain constant, the use of renewable energy will decrease by 1.26% if the use of FOS increases by 1%. This result is in line with Çıtak and Pala's research. [21], that on the other hand, countries with sufficient energy resources have been overusing fossil resources without considering their negative impact on the environment. This is due to population growth and high consumption associated with population. In comparison, Bayraktutan, Y., Ay, H.M., and Şahbaz, N. [22], because imported fossil energy has damaged the environment. These countries face increasing international energy dependency issues as well as environmental damage.

4.4. Economics growth on Renewable energy

Our study found that the ECO coefficient is negative 0.008%, which means that, assuming other variables are constant, the level of renewable energy use will decrease by 0.008% if the ECO coefficient increases by 1%. The same results were found in the research of Shahbaz, M., Raghutla, C., Chittedi, K.R., Jiao, Z., and Vo [23]. Most developing countries provide more funds for development than renewable energy.

5. CONCLUSION

Renewable energy sources are a very important issue in today's world because countries that use them will reduce their dependence on imported fossil fuels because these energy sources are clean, do not harm the environment, and have less negative impact. If countries want to generate renewable energy consumption and production, they must increase their efforts.

This study aims to determine how the relationship between carbon dioxide emissions, fossil fuels, energy imports, and economic growth affects renewable energy consumption in three Organization of Islamic Cooperation (OIC) member countries in Southeast Asia from 2000 to 2020. The results show that C02, FOSIL, and ECO have no influence on renewable energy use in the three selected OIC countries; in contrast, ENG shows a positive correlation between renewable energy consumption and economic growth.

The research is based on the impact of sizable energy imports on renewable energy use. This is the basis of the policy recommendations. The government should continue to maintain and gradually improve the quality of energy imports, especially with regard to imports to support domestic renewable energy development. If CO2 emissions increase, it is possible that the use of renewable energy will decrease. I This can be anticipated by increasing the development of renewable energy such as geothermal, hydropower, and bioenergy utilization. This will allow the use of renewable energy to increase and become more accessible to the general public. Since the public contributes most of the fossil energy into the country's use, there should be policies that suppress the use of fossil energy among the public when it comes to the overall use of fossil energy. The use of electric vehicles and energy from rooftops can anticipate this. Nonetheless, the economic growth of each of the three countries will face significant challenges as increased economic growth is directly correlated with increased use of non-renewable energy is required. Therefore, the solution to this problem is that every country should allocate significant funds to develop renewable energy. This will make renewable facilities and energy easily accessible so that the use of renewable energy increases every year.

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