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Article

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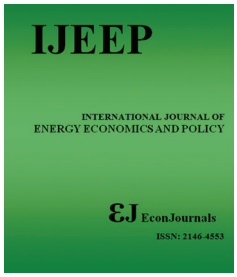

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Renewable Energy, GDP (Gross Domestic Product), FDI (Foreign Direct Investment) and CO_2 Emissions in Southeast Asia Countries

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ABSTRACT

The increasing rate of economic growth and globalization of the global economy has raised concerns regarding sustainable development, and renewable energy is being explored as a possible solution. The interrelationship between economics, environment, and energy consumption has been widely researched amongst academics worldwide; however, due to the inconsistent results, further exploration is needed to clarify the matter. Thus, this study seeks to investigate potential factors such as foreign direct investment (FDI), gross domestic product (GDP), and carbon dioxide (CO_2) emissions that impact renewable energy consumption in countries within Southeast Asia. This research suggests that FDI flows bring positive aspects to the region's renewable energy sector while GDP and CO_2 emissions have negative impacts. These findings can thus be employed as baseline information for future policies that strive to expand renewable energy activities in the region.

Keywords: Renewable energy, GDP, FDI, CO_2, Southeast Asia
JEL Classifications: C24, O13, Q2, Q43

1. INTRODUCTION

The relationship between energy, the economy, and the environment is a crucial factor in the development process of any nation (Azam et al., 2015). It is essential to ensure that all three elements are managed in a balanced manner in order to guarantee adequate progress. Energy use plays an important role in the country's socioeconomic development and is a driving factor for economic growth and living standards (Asghar, 2008; Tripathi et al., 2016). Economic growth has been linked to increased energy use since the early 1900s, and this correlation has become increasingly evident as modern-day technology has advanced (Madlener and Sunak, 2011). Specifically, in the demand aspect, energy is applied to industrial production, transportation, trade and services to improve the quality of human life(IEA, 2009). As the economy grows, more people will need to consume products, stimulating businesses to participate in energy production and consumption. Regarding supply, energy is an important production element besides capital, labor, and raw materials.

Energy production and consumption account for almost two-thirds of all global greenhouse gas emissions, leading to climate change, ozone depletion and other environmental issues (Gielen et al., 2019; Sperling and Yeh, 2009). Excessive energy consumption has become a major problem for the environment, as it tends to generate a variety of adverse effects. There is an urgent need for countries around the world to develop more sustainable forms of energy production and consumption. Renewable energy is also a sustainable energy source with low emission capacity, playing an important role in reducing CO_2 emissions to 50% by 2050 (IEA, 2009). These resources have the potential to reduce greenhouse gas emissions while providing sustainable electricity generation at lower costs than traditional sources (Varun et al., 2009). Using renewable energy ensures the development of the economy's

production process but also minimizes negative impacts on the environment.

In recent years, the role of renewable energy has been increasingly emphasized and has attracted the attention of scholars and energy policy analysts around the globe. Most studies use the Johansen co-linkage test and the Granger causal relationship test to show the relationship between renewable energy and economic plates such as GDP and FDI (Grabara et al., 2021; Apergis and Payne, 2015; Lee, 2013; Sadorsky, 2009) and environmental variables such as CO_2 output, greenhouse effect output (Leitão, 2014). Despite the number of existing studies on the effects of renewable energy use, their results vary significantly due to differences in research data sets and various context-dependent factors. Specifically, analyses of the mid-level impacts of renewables, such as the economy and environment, are far more developed than those assessing the influence of economics and ecology on renewable energy deployment.

Southeast Asia's rapid population and economic growth in the past two decades - averaging an impressive 5-6% a year - has highly impacted its average urbanization rate and per capita income. In 18 years, between 2000 and 2018, Southeast Asia witnessed a remarkable 10% increase in its percentage of population residing in urban areas (IEA, 2017). This shift from rural to urban settlements has triggered a surge in energy demand, with an overall 80% jump since 2000 (IEA, 2019). Worryingly, this rising need for energy has largely been fulfilled by fossil fuel sources, exploiting natural resources and posing severe threats to public health through environmental pollution. Paired with industrial development to sustain such growth rates, developing countries within the region are facing tremendous pressure on their ecosystems.

This study examines several factors affecting renewable energy use in Southeast Asian Countries, including GDP, FDI and CO_2 emissions. Data for this analysis was taken from five countries (Laos, Myanmar, Malaysia, Thailand and Vietnam) over a 15-year time frame from 1990 to 2015. The empirical evidence generated from this research will add new insights into the relationships among renewable energy, economic growth and environmental variables, thus, can assist national governments in creating strategies and policies that promote renewable sources of energy for sustainable development purposes.

2. THEORETICAL BASIS, HYPOTHESES AND RESEARCH MODELS

2.1. GDP and Renewable Energy

Much literature has been devoted to exploring the link between renewable energy consumption and economic growth (Chen et al., 2020). This body of work has primarily examined four plausible hypotheses including the feedback hypothesis, where it is assumed that renewable energy consumption and economic growth have a mutually beneficial relationship (Apergis and Danuletiu, 2014; Apergis and Payne, 2010; 2011; 2012; Belaïd and Zrelli, 2019; Kahia et al., 2017; Lin and Moubarak, 2014; Narayan and Doytch, 2017; Salim et al., 2014; Li et al., 2022; Salim and Rafiq, 2012); the growth hypothesis, which proposes that only renewable energy consumption leads to economic growth (Bhattacharya et al., 2016; 2017; Fang, 2011; Inglesi-Lotz, 2016; Magnani and Vaona, 2013; Rafindadi and Ozturk, 2016); the conservative hypothesis, suggesting that only economic growth leads to an upsurge in renewable energy consumption (Inglesi-Lotz and Dogan, 2018; Menyah and Wolde-Rufael, 2010); and finally, the neutrality hypothesis which suggests that there is no significant relationship between these two variables (Bulut and Muratoglu, 2018; Menegaki, 2011).

2.2. GDP, FDI and Renewable Energy

FDI into renewables is also linked to overall economic performance. Studies suggest that FDI inflows into specific countries tend to increase after they become involved in renewable energy initiatives or make commitments to build up their infrastructure related to renewable energies (OECD, 2017). Grabara et al. (2021) studied the cases of Kazakhstan and Uzbekistan and revealed that GDP and FDI had an influential impact on renewable energy output. Azam et al. (2015) found similar evidence for Thailand, Malaysia and Indonesia, where FDI and GDP both substantially affected energy consumption. Doytch and Narayan (2016) analyzed FDI and its position regarding energy demand, demonstrating that FDI was a necessary resource to facilitate enterprise growth and contribute to advances in energy efficiency technologies. This evidence suggests that supportive solid policies can help attract domestic and foreign capital into developing renewable technologies, thereby helping spur economic activity in these countries.

2.3. GDP, Renewable Energy and CO_2 Emissions

The recent shift towards renewable energy sources, fuelled by economic growth, has been seen as a potentially crucial part of the global effort to reduce and mitigate CO_2 emissions. Indeed, various studies have identified a relationship between investment in renewable energy and reduced CO_2 emission levels. For example, Razmjoo et al. (2021) found that investing heavily in renewable energies like solar and wind resulted in reduced CO_2 emissions compared to investing in fossil fuels alone. Ryan et al. (2011) pointed out a correlation between renewable energy use and lower CO_2 emission levels, particularly when combined with other mitigation strategies such as energy efficiency measures and carbon pricing policies.

Studying the relationship between economic growth, CO_2 emissions and renewable energy consumption has been the focus of numerous studies. Ben Jebli et al. (2015) analyzed the case of 24 sub-Saharan African countries between 1980 and 2010 and found, through a Granger causal method, that renewable energy consumption had a one-way causal link to CO_2 emissions in the short term. Leitão (2014) determined that a positive correlation existed between renewable energy consumption and economic growth, with a one-way causal relationship present during the 1970-2010 period in the case of Portugal. Pao and Tsai, (2011) looked into the same issue but within BRIC countries and made similar determinations regarding their study frame, which encompassed a 30-year timespan from 1980 to 2007. Zoundi (2017) contends that renewable energy consumption has a detrimental effect on the emission of CO_2. Research conducted by

Apergis and Payne (2015) in South American states yielded valid proof that per capita CO_2 emissions have a constructive impression on the long-term use of renewable energy and a bidirectional causal linkage between both variables from 1980 to 2010 period.

The unidirectional and bidirectional effects are very diverse in the research results. This contributing knowledge provides valuable insights for understanding the complex interactions involved with CO_2 emissions, economic growth and renewable energy consumption. Within the scope of this research, the author chooses to study the factors affecting the consumption of renewable energy, including FDI, GDP and CO_2, through experimental testing of the following hypotheses:

- H_1: GDP has a positive impact on renewable energy consumption
- H_2: FDI has a positive impact on renewable energy consumption
- H_3: CO_2 output has a negative impact on renewable energy consumption

3. RESEARCH METHODOLOGY

The study used the Ordinary least squares (OLS) regression model to analyze panel data of 5 countries to identify factors affecting renewable energy output, including Laos, Myanmar, Malaysia, Thailand, and Vietnam in the 15 years from 1990 to 2015. The proposed mathematical model follows:

$$RE = f(GDP, FDI, CO_2)$$

All variables have been converted to log-linear (LN) form. This conversion aims to obtain a model with the elasticity of variables and reduce the sharpness of time series data for consistent and reliable estimates. The new transformation of the model in log form is as follows:

$$\ln RE = \beta 0 + \beta 1 \ln GDP + \beta 2 \ln FDI + \beta 3 \ln CO_2 + \varepsilon i$$

The interpreted and measured variables are presented in Table 1. The variables are aggregated from the World Bank, with RE as a dependent variable and complemented by additional independent variables, including FDI. GDP and CO_2.

4. EMPIRICAL RESULTS

4.1. Data Analysis

The data analysis process began with gathering a dataset that spanned a 26-year period, 1990 to 2015, and comprised 520 observations from 5 different countries. In order to ensure that the data was accurate and reliable, various tests were conducted to ascertain its quality beforehand, along with an examination of linear relationships that might exist within. The successful execution of the pre-assessment tests enabled the trustworthiness of the resultant model after data cleaning (Maidment and Curry, 2018).

Descriptive statistics (Table 2) provide an understanding of the characteristics and trends of data, allowing for analysis of the underlying factors influencing renewable energy. In this analysis, we found significant differences in the value of variables across countries, indicating an unequal distribution of factors among nations. Moreover, to effectively analyze these differences, it is necessary to ensure a normal distribution among the dependent variables – this can be tested through the Jarque-Bera test, which evaluates standard deviation statistically. Indeed, when testing all observed variables at a 95% confidence interval ($P < 0.05$), the results showed that all variables satisfied standard distributions according to the Jarque-Bera test.

Table 1: Research variables and expected relationships

Variable observation	Variable description	Measure	Expected relationship
RE	Renewable electricity output	% of total electricity production	+
FDI	FDI inflows	% of GDP	+
GDP	GDP per capita	Current US dollars	+
CO_2	CO_2 emissions	kt	–

4.2. Correlation Coefficient and Multicollinearity

The correlation coefficient demonstrates the degree to which two variables are related or associated (Mukaka, 2012). Results from Table 3 depict that the correlation coefficient between the independent and dependent variables was found to be strong, indicating a strong and significant correlation between them (Schober et al., 2018). However, it was noted that we could not find a significant correlation between the independent variables.

The multiple linear regression model requires that independent variables have little to no correlation with each other to produce reliable results; when this requirement is not met, a multicollinearity event occurs (Shrestha, 2020). An effective way of detecting whether the multi-linear phenomenon is taking place is to use the variance magnification factor (VIF) – if the VIF value exceeds 10, it is considered a signifier of this occurrence (Chan et al., 2022). The results of the multicollinearity test in Table 4 show that the VIF of each independent variable has a value of <10 – this supports that there is no ongoing multi-linear phenomenon.

4.3. Multivariate Regression

The study conducted regression in a random method between variables.

According to the results of a residual correlation phenomenon test conducted through regression analysis (Table 5), the Durbin-Watson value (DWV) of 0.19 lies within the acceptable range of $0 < d < 1$, indicating a positive correlation between random errors. The corrected R2 value for this model also reaches an impressive 0.7457, signifying that independent variables explain 74.57% of the variation in the LRE variables. The unnormalized regression equation shows that foreign direct investment inflows have the most decisive influence on renewable electricity production, followed by GDP per capita and CO_2 emissions. The multivariate linear regression equation is written from the results table below:

$$\ln RE = \beta 0 - 0.1664 \ln GDP + 0.2150 \ln FDI - 0.3708 \ln CO_2 + \varepsilon i$$

The inflow of FDI ($\beta = 0.215$, se = 0.06) strongly influences renewable electricity output. The inflow of FDI is highly

Table 2: Descriptive statistics

Descriptive statistics value	LRE	LGDP	LFDI	LCO_2
Mean	3304549	6909317	1246670	1023956
Maximum	4605170	9334243	2479851	1248021
Minimum	1586986	3897212	−2870117	6234411
SD	1055647	1412729	0.762062	1945541
Skewness	−0.242263	−0.212045	−1936142	−0.596470
Kurtosis	1424992	1996191	9426601	2009565
Jarque-Bera	1470850	6432214	3049355	1302203
Probability	0.000640	0.040111	0.000000	0.001487
Observations	130	130	130	130

Table 3: The correlation coefficient between variables

Variable	LCO_2	LFDI	LGDP	LRE
LCO2	1.0000			
LFDI	0.0628	1.0000		
LGDP	0.7083	−0.1252	1.0000	
LRE	−0.8314	0.1403	−0.7262	1.0000

Table 4: Multicollinearity test

Variable	Coefficient Variance	Uncentered Bright	Centered Bright
LGDP	0.0023	5.3483	2.1303
LFDI	0.0040	3.9401	1.0657
LRE	0.0012	6.0873	2.1052
C	0.0757	3.4759	-

Table 5: Results of regression analysis

Variable	Coefficient	SE	t-Statistic	Prob.
LGDP	−0.1664	0.0484	−3437498	0.0008
LFDI	0.2150	0.0634	3388255	0.0009
LCO_2	−0.3708	0.0349	−1061023	0.0000
C	7983234	0.2752	2900724	0.0000
R-squared	0.7517	Mean dependent var		3304549
Adjusted R-squared	0.7457	S.D. dependent var		1055647
S.E. of regression	0.5522	Akaike info criterion		1606847
Sum squared resid	3569340	Schwarz criterion		1695079
Log likelihood	−1004450	Hannan-Quinn criter.		1642698
F-statistic	1271563	Durbin-Watson stat		0.193109
Prob (F-statistic)	0.0000			

significant in raising renewable electricity output (Grabara et al., 2021). The use of green energy practices is often put into place by foreign businesses, which tend to have a higher standard for environmental protection (Doytch and Narayan, 2016; Eskeland and Harrison, 2003). They are more likely to draw from renewable energy sources and promote energy-saving initiatives. Capital and technology are both essential resources for achieving renewable energy goals and are the core of foreign direct investment (FDI) enterprises (Brunnschweiler, 2010). All in all, FDI is essential for harnessing the potential benefits associated with increased utilization of renewable energy sources, given its links to capital and technology resources.

GDP ($\beta = -0.166$, se = 0.05) has a negative impact on renewable consumption. GDP's reliance on resource-based production through inexpensive fossil fuels restricts its ability to adopt alternative, more costly green power (Grabara et al., 2021). This dependence on traditional resources serves as a major obstacle to efficiently shifting away from these non-renewable forms of energy, which hampers efforts to incorporate renewable sources into global economies.

The CO_2 index ($\beta = -0.371$, se = 0.03) is inversely proportional to renewable energy production because high CO_2 emissions mean a large proportion of fossil or non-renewable energy sources are used. To combat the detrimental effects of climate change, it is imperative to minimize the CO_2 emissions generated on a global scale.

5. POLICY IMPLICATIONS

The policy is a crucial factor in developing solutions to the problem of transitioning from traditional energy sources to sustainable energy sources. In recent years, there has been an increase in foreign direct investments (FDI) for clean technology projects to reduce carbon output and stimulate economic growth; however, researchers have found that FDI does not necessarily lead to increased amounts of renewable electricity output due to the lack of investment incentives, appropriate legal frameworks governing these investments and regulating standards (Fatima et al., 2021). This suggests that supportive solid policies can help attract domestic and foreign capital into developing renewable technologies, thereby helping spur economic activity in these countries (Mahbub et al., 2022). Nepal et al. (2021) state that Southeast Asia has deployed policies to attract FDI into the renewable electricity industry, while Grabara et al. (2020) concludes that while these policies are beneficial, they may not positively influence renewable electricity output due to a lack of standardization among different countries in regards to resources available for production and protection of investors' interests. Ulewicz et al. (2021) suggest that adjusting policy mechanisms could better promote renewable energy investments, which may lead to increased use of renewable electricity and a more sustainable future. Lee (2019) claims that nations must dedicate time and resources to FDI attraction to take advantage of the increasing focus on environmental issues in the economy. Implementing strategies to finance and develop infrastructure oriented towards renewable energy sources and low-carbon technologies will be crucial, along with policies specifically designed to reduce total energy consumption at a systemic level. Examples include instituting higher efficiency appliance standards and taxing products that utilize high amounts of energy (OECD/IEA, 2018). Additionally, governments should invest in the research and development field for efficient technologies that curb overall energy use (Yu et al., 2021). All of these measures can add up to create noticeable progress in terms of sustainability.

In order to reduce CO_2 emissions and the effects of climate change, incentivizing the development of renewable energies is key to a sustainable future. Establishing incentive mechanisms to develop renewable energy sources is vital in this process; with easily accessible and cost-effective solutions to reduce emissions, people and organizations are likely to be encouraged to tap into alternative forms of energy. Renewable energy costs have decreased significantly in recent years; however, governments

must still create fiscal incentives to encourage industry to invest in this energy. Through enticing rewards such as tax credits, subsidies and other types of financial assistance, authorities can create incentives that will motivate businesses and individuals to foster a cultural shift from traditional sources of energy like coal and gasoline and to use renewable resources such as sun, water or wind power. Consequently, by implementing these stimulus systems, many more people can be encouraged to take on technological advancements for cleaner and greener energy initiatives.

6. CONCLUSIONS

The study sought to identify the interrelationships between foreign direct investment (FDI), GDP, and carbon dioxide emissions (CO_2) and how they can impact renewable energy consumption within 5 select Southeast Asian countries. Through data gathering from secondary sources, data processing and analysis, the results concluded that all three aforementioned factors had a statistically significant effect on renewable energy consumption in these countries (Laos, Myanmar, Malaysia, Thailand and Vietnam). These findings demonstrate the connections between various economic variables, such as FDI, by revealing its positive influence on renewable energy consumption. Consequently, lending further credence to increased FDI supports sustainable development in Southeast Asia.

In carrying out research, certain limitations are unavoidable, paving the way for future studies. Additionally, the sample of five ASEAN countries out of eleven may need to be more generalizable due to data limitations; further analysis could involve different regional and economic groupings to provide a more thorough and intensive analysis. Lastly, the time series used was restricted to 26 years due to the imperfect availability of information: however, if data could be extended, this would create a more reliable conclusion. In this case, the author researched three factors, but more could be added to enable a more comprehensive analysis.

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