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# The Impact of Financial Development on Renewable Energy Consumption: The Case of Vietnam and Other ASEAN Members

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**Abstract:** The purpose of this study was to evaluate the impact of financial development and renewable energy consumption in Vietnam and some selected countries in Southeast Asia. After researching over the period from 1970 to 2022, using quantitative analyses, including the ordinary least squares (OLS), fixed effects method (FEM), and random effects method (REM), and measuring the Driscoll–Kraay standard errors to assess cross-dependence between countries as well as a Dynamic Ordinary Least Squares (DOLS) estimation analysis to evaluate the robustness of the research, the research results confirm that financial development has a negative impact on renewable energy consumption, which reflects the important role of fossil energy sources in meeting energy consumption demand. Similarly, increased per capita income negatively affects renewable energy consumption. This study also confirms the positive impact of foreign direct investment on renewable energy use.

**Keywords:** renewable energy; fossil fuel; income; foreign direct investment; energy; financial development



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## 1. Introduction

Socio-economic development in countries leads to increasing demand for energy and therefore increased pressure on the environment (Le et al. 2022). A high energy demand increases the possibility of toxic gas emissions, which causes the greenhouse effect, and thereby increases social costs and economic efficiency. In particular, countries still use fossil energy in their economies because this energy source is cheaper, while renewable energy sources do not contribute much to energy demand. Therefore, renewable energy sources do not contribute much to meeting the energy demand. This product has a higher cost, so it cannot create a competitive advantage in the short term.

Renewable energy sources have many advantages; that is, this energy source produces low-carbon emissions and therefore has a reduced impact on the environment, thereby reducing related costs such as social costs and health and environmental costs. Therefore, all countries want to update growth models based on using renewable energy sources and limiting the use of fossil energy sources. To orient investment in the use of renewable energy, the economy needs to increase financial resources to invest in renewable energy sources. To do this, the financial market plays a very important role in allocating the economy's investment capital to this energy source and, at the same time, limiting the allocation of investment resources into potential fossil energy with its high pollution potential. According to Gök (2023), financial development reduces financial risks and increases risk diversification, as well as minimizes debt costs, thereby stimulating investment and financial capital flows. The development of the banking sector is closely associated with financial development. Furthermore, financial development generates higher returns on total assets and increases credit in banks, which thus stimulates investment in renewable energy sources. The banking sector provides resources for low-cost renewable energy development and, at the same time, provides greater liquidity for investors to accumulate capital along with technological innovation in the renewable energy sector, so some studies suggest that financial development has a positive impact on renewable energy use.

Vietnam, in particular, and Southeast Asia, in general, have many achievements in socio-economic development and are considered the region with the fastest development and highest integration ability. Therefore, the Southeast Asia region has a continuously increasing level of energy consumption every year, where fossil energy sources still play the most important role in meeting the energy consumption demand. Therefore, renewable energy has not contributed much to the region's energy consumption needs; for example, Singapore is still 100% dependent on fossil energy. Indeed, renewable energy only meets about 31.78% of the energy demand in selected countries in Southeast Asia, and the use of renewable energy is gradually decreasing under the increasing pressure of current energy needs. According to Nguyen and Nguyen (2021), renewable energy only meets a small percentage of the energy demand—specifically, 58.54% in Cambodia, 43.21% in Indonesia, 50.48% in Vietnam, 0.48% in Singapore, 6.32% in Malaysia, and 0.05% in Brunei. This reflects that renewable energy has not made much practical contribution to the energy demand in Southeast Asia.

In developing renewable energy, it is impossible not to mention the role of the financial market as a place to provide financial resources for investment in renewable energy development. When financial resources prioritize investment projects to develop renewable energy, investors are often given priority in accessing capital with low interest rates to thus help expand renewable energy investment, and vice versa. Fossil energy projects have higher interest rates and fewer advantages than renewable energy development projects. Therefore, it can be said that the financial market has a role in guiding the development of renewable energy sources. Therefore, the goal of this study was to evaluate the financial development of renewable energy consumption in Vietnam and other selected Southeast Asian countries. This study aimed to evaluate the role of the financial market in renewable energy development. This study was set in the context that recently, at the United Nations Conference on Climate Change 2021 (so-called COP26), the dangers of climate change, such as global warming, for which fossil energy sources contribute the highest proportion, were discussed. There are still many problems to address, especially in terms of coal usage. The goal of COP26 was to push countries to pursue a net-zero policy to be achieved by 2050, and the net-zero phenomenon occurs when the amount of greenhouse gases emitted is no greater than the amount removed from the atmosphere. Therefore, economies need to increase financial resources; transfer technology in production to optimize renewable energy production; and update growth models based on contributions concerning technology, innovation, and intellectual labor. The target was also repeated at COP27 in 2022, which took place in Egypt, calling on countries and businesses to carry out "greenwashing" and measures to support the countries most affected by climate change. At the same time, there was a wave of criticism directed toward countries for lacking timely action regarding climate change and reducing dependence on renewable energy. Avoiding a repeat of the critical discussions at COP27, at the COP28, which took place in Dubai, countries significantly promoted the first assessment of global efforts under the Paris Agreement on climate change and shaped the formation of a loss and damage fund, and these topics were still controversial. The conference reaffirmed reaching the net-zero emission target by 2050 and called on countries to act responsibly (World Economic Forum 2023; United Nations 2022).

Therefore, it is evident that the importance of conducting this research is to evaluate the impact of financial resources on the development of renewable energy sources. The roles of finance in particular and the financial market in general have become quite important in promoting the renewable energy market, and this is a topic that has been discussed since COP26. Indeed, the topics of criticism and irresponsible actions were discussed at COP27, but by COP28, most countries had taken more practical actions, especially creating a foundation for forming a loss and damage fund to provide financial resources for vulnerable countries. Prakash (2018) indicated that Southeast Asia is globally considered one of the most vulnerable regions to climate change, especially the situations of rising sea levels, heat waves, floods and droughts, and unpredictable weather events.

From the above discussion, the research question of the study should be declared as follows:

Does the financial development impact on renewable energy use in selected Southeast Asian countries?

In addition to the introduction mentioned above, the rest of the study is presented as follows: Section 2 discusses the literature review, next is data collection as well as research methods, and the results and discussion of the results are last, as well as general conclusions of the study.

## 2. Literature Review

The financial market plays a very important role in the economy, especially the ability to allocate capital in the economy (Mukhtarov and Mikayilov 2023). The financial market has the ability to direct capital flows into businesses with high scientific and technological content and businesses that use little energy or use fossil energy sources, while the financial market has the ability to limit investment capital flows into energy-consuming businesses and production based on fossil energy sources. It can be said that the financial market plays an important role in circulating capital into green and environmentally friendly production.

Lin and Okoye (2023) argued that the Kyoto Protocol and the Paris Agreement have set a low global average temperature increase in order to deal with health and environmental conditions related to greenhouse gas emissions. Therefore, reducing carbon emissions and facilitating renewable energy is a top priority in countries today. Researching 35 high-income countries during the period 1996 to 2020, Lin and Okoye (2023) argued that there is a one-way causal relationship from financial development to renewable energy production and from governance to greenhouse gas emissions. Furthermore, financial development and governance both have small effects on greenhouse gas emissions, so the impact between them is weak.

Gök (2023) argued that the devastating effects of climate change require the use of renewable energy sources and a reduction in fossil energy sources in order to achieve sustainable development, reduce greenhouse gas emissions, and protect community health. Gök (2023) also believed that there is a positive and significant relationship between financial development and renewable energy, so it is necessary to provide more effective and less expensive capital sources for investors to promote renewable energy. Khan and Rana (2021) argued that environmental degradation occurs due to economic growth, industrialization, urbanization, and globalization, so reasonable solutions are needed for countries to switch from non-renewable to renewable energy but still ensure an uninterrupted energy supply and not undermine growth. Zheng et al. (2024) also indicated that economic development is a factor that affects the environment, and it becomes more serious when people are inadequately educated about its consequences. In fact, better education and better institutional quality have the potential to significantly reduce emissions and sustain sustainable development.

Policy tools and financial support are effective tools for promoting renewable energy innovation around the world. Li and Shao (2023) argued that financial market development can expand renewable energy industries. Most studies suggest that there is a relationship between financial development and renewable energy consumption, and moreover, it also impacts renewable energy innovation. This study covers 37 OECD member countries from 1990 to 2019 and suggests that as financial development increases, its impact on renewable energy innovation decreases; environmental policy becomes stricter, and its impact grows rapidly. This implies that financial development is associated with larger increases in renewable innovation in countries with medium levels of financial development and strong environmental policies to enhance innovation. Another possibility: Horky and Fidrmuc (2024) also affirmed that ASEAN financial intermediaries and banks in favor of carbon-intensive energy production have a negative impact on renewable energy consumption. However, in countries with developed capital markets, as in the case of the EU, there is often a positive influence on energy consumption, thereby confirming financial support

policies for the green energy transition process. This requires governments to support increased financialization of the energy market and legal support for banks and financial institutions supporting renewable energy business models.

An indispensable factor affecting the development and consumption of renewable energy is economic growth. Ergun and Rivas (2023) argued that this relationship can exist in both the long and short term, and the impact depends on the socio-economic conditions and energy consumption of each country. Specifically, there is a non-linear relationship between income and renewable energy consumption in eight emerging Asian countries, meaning that there is both a positive relationship and a negative relationship between economic performance and renewable energy consumption, and this relationship is U-shaped. When income is lower, renewable energy consumption decreases, and when income is higher, consumption of renewable energy increases because higher incomes help countries have enough financial resources and advanced manufacturing activities, so it is easier for them to switch to renewable energy consumption than other countries with lower income levels. Another study by Bhuiyan et al. (2022) argued that there is a two-way relationship between economic growth and renewable energy consumption, meaning that economic growth promotes renewable energy consumption and vice versa; renewable energy consumption promotes growth.

A study by Chen et al. (2023) in China argues that the country has achieved economic development and environmental improvement. Indeed, China implements a dual control plan in energy consumption based on renewable and non-renewable energy. Chen et al. (2023) suggested that there is a unidirectional relationship between renewable energy sources and reduced air pollution, while non-renewable energy sources increase pollution. However, China still depends on fossil energy sources to meet rising energy demand and requirements for economic development. In a similar study in China, Li et al. (2022) explained that there is an N-shaped relationship between renewable energy consumption and economic growth, which implies that when the economy develops highly, there are more investment resources for renewable energy to meet the needs of the economy, and thus the level of environmental pollution is reduced. However, fossil energy sources still become important due to their low cost and ability to meet increased energy consumption needs, and therefore it takes time for the economy to be able to innovate its growth model, for example, a growth model of technology investment, clean energy consumption, and knowledge-intensive production. This is also explained through the research of Simionescu and Plopeanu (2023), suggesting that European countries have a high level of economic development and, at the same time, they are pursuing a policy of not polluting the air, water, and soil to build a clean living environment and healthy ecosystem and aim to be carbon neutral by 2050.

In addition to the factors mentioned above, it can be seen that economic integration significantly develops renewable energy, and this is explained as follows: the integration process helps countries have the ability to attract renewable energy flows. FDI capital or international trade in procurement and import serves the investment process in renewable energy sources. Dossou et al. (2023) showed that FDI has a positive impact on renewable energy consumption, meaning that an increase in foreign direct investment leads to a 0.05 increase in renewable energy for sub-Saharan African countries. Another possibility: Nguyen and Nguyen (2021) argued that expanded trade has a positive impact on renewable energy, and this evidence was also confirmed by Qamruzzaman and Wei (2020), which confirms the benefits of economic integration in developing green energy sources and meeting long-term economic development. Regarding human capital, Adepoju et al. (2022) argued that human capital has the potential to increase the penetration of renewable energy sources in the world. Indeed, high quality human capital is associated with an increased understanding of sustainable development and energy consumption. At the same time, higher quality human resources are capable of meeting production with its high scientific and technological content, and these activities often consume less energy, contributing to environmental protection.

## 3. Data and Methodology

This study used data from selected Southeast Asian countries, including Thailand, Philippines, Vietnam, Laos, Indonesia, Malaysia, and Singapore. Data were collected from the World Bank and the International Monetary Fund; some other data were collected from the Statistics Department of each country published annually. Data collection period was from 1970 to 2022. Overall, most data were collected from the World Bank.

The study was developed using the study of Gök (2023) and adjusted to suit the objectives discussed in this study. The regression equation used is as follows:

$$REC_{it} = \beta_0 + \beta_1 FI_{it} + \beta_2 GDP_{it} + \beta_3 TRADE_{it} + \beta_4 FDI_{it} + \beta_5 HUMAN_{it} + \varepsilon_{it} \quad (1)$$

In order to check the robustness, we also used another measurement for FI, domestic credit to the private sector. It can be shown as follows:

$$REC_{it} = \beta_0 + \beta_1 DC_{it} + \beta_2 GDP_{it} + \beta_3 TRADE_{it} + \beta_4 FDI_{it} + \beta_5 HUMAN_{it} + \varepsilon_{it} \quad (2)$$

The new point of this study can be explained as follows: the authors evaluate financial development based on renewable energy consumption and add the impact of economic integration and human capital in the research model for a comprehensive impact on renewable energy consumption. Indeed, the Southeast Asia region is located on the international seaway connecting Europe and Asia and is a place with dynamic economic development and deep economic integration. Typically, Singapore, Vietnam, Malaysia, or Thailand have a high level of FDI attraction and very high trade openness, always above 100% of GDP in recent years.

REC is renewable energy consumption, measured as a % of total energy demand; FI is financial development, measured by M2 compared to GDP; DC is also another proxy for financial development and measured by monetary sector credit to the private sector (% of GDP). This measurement is supported by Puatwoe and Piabuo (2017) and Nguyen and Nguyen (2021); GDP variable represents economic growth, measured by per capita income (constant 2015, USD), and this measurement is supported by Ergun and Rivas (2023); TRADE is a variable representing trade openness, measured in % of GDP, and this variable is confirmed by Nguyen and Nguyen (2021); FDI variable represents foreign direct investment, measured as % of GDP, and is confirmed by Dossou et al. (2023); HUMAN is a variable representing human capital, measured by the rate of investment in education as a % of GDP, and this factor is also confirmed by Adepoju et al. (2022).

This study used quantitative regression analysis methods such as the ordinary least squares, fixed effects method, and random effects method. This study used F and Hausman tests, heteroscedasticity and autocorrelation, and FGLS regression methods. In addition, this study also performed regression according to Driscoll–Kraay standard errors to assess cross-dependence between countries in the region. This study also used Dynamic Ordinary Least Squares Estimator (DOLS) analysis to evaluate the robustness of the research results. According to Hoechle (2007), Driscoll–Kraay standard errors are well-calibrated when cross-sectional dependence is present. In addition, by relying on large T asymptotics, Driscoll–Kraay indicated that the standard nonparametric time series covariance matrix estimator can be modified, and it is robust for the forms of cross-sectional or temporal dependence. Further, revising the standard error estimates in this way guarantees that the covariance matrix will be consistent and independent of the cross-sectional dimension. Another possibility: Wang and Wu (2012) indicated that the DOLS estimator can be obtained by adding the lead and lag of $\Delta x_t$ to soak up the long-run correlaton between $u_{1t}$ and $u_{2t}$ as follows:

$$y_t = x_t'\beta + d_{1t}'\gamma_1 + \sum_{j=-q}^{r} \Delta x_{t+j}'\delta + v_{it}$$

## 4. Results

*Descriptive Statistics*

Table 1 presents the statistical results describing the variables in the estimated model. For renewable energy consumption, this index reaches an average value of 31.78%, reflecting that renewable energy contributes 31.78% of energy consumption, and the remaining percentage is the contribution of fossil energy. The standard deviation is approximately 24.97%, feflecting that renewable energy consumption has a huge difference among economies. For financial development, this index reaches 69.80% of GDP, and the standard deviation is approximately 39.74%, which shows that the financial development index of Southeast Asian countries is quite high. However, there are differences in this index between countries in the region.

**Table 1.** Descriptive statistics.

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| REC | 31.78459 | 24.97082 | 0.19 | 88.4 |
| FI | 69.80555 | 39.74305 | 7.10931 | 148.9482 |
| GDP | 5964.523 | 12,802.33 | 78.86576 | 82,807.65 |
| TRADE | 128.5124 | 104.0195 | 9.105691 | 437.3267 |
| FDI | 4.387393 | 5.636992 | −2.75744 | 32.69117 |
| HUMAN | 104.061 | 9.436019 | 57.41764 | 125.0868 |

*Source: Authors' analysis.*

Regarding GDP per capita income, the selected Southeast Asian countries reach an average GDP per capita of 5964.52 USD/person/year, and the standard deviation is about 12,802.33 USD/person/year; therefore, there are differences in per capita income between countries in the region. Regarding foreign direct investment (FDI), this ratio accounts for an average of 4.38% of GDP. Singapore has the highest FDI attraction in the continent, where FDI reaches 32.69% of GDP. Regarding trade openness, this index reaches an average of 128.51% of GDP and is quite high. Singapore's trade openness level is also the highest on the continent, reaching 437.32% of GDP.

Table 2 indicates that Laos, Vietnam, and Indonesia have higher levels of renewable energy consumption compared to other countries, while Malaysia and Singapore have very low levels of renewable energy consumption, and these countries still depend on fossil energy. This result shows that renewable energy sources still make a great contribution to the economies of Laos, Vietnam, and Indonesia, but do not much contribute to economic development in Malaysia and Singapore, as the share of renewable energy in these two countries averaged 4.41% and 0.54% total energy demand, respectively.

Regarding financial development, Singapore, Thailand, Vietnam, and Malaysia have high levels of development, while Laos and Indonesia have lower levels of development. During the economic integration process, countries such as Singapore, Thailand, Vietnam, and Malaysia have quite high trade openness and at the same time more developed financial markets than Laos, while Indonesia has a large population and economy size; this country's economy exhibits differences between regions.

In terms of GDP, Singapore has the highest average income, followed by Malaysia, while the Philippines, Vietnam, and Indonesia have a similar GDP per capita. Singapore's GDP per capita reached 82,807.65 USD/person/year in 2022 and was 7 times higher than Malaysia's per capita income of 11,971.93 USD/person/year in 2022. Further, the GDP per capita of the Philippines, Vietnam, and Indonesia was, respectively, 3498.50, 4163.51, and 4787.99 USD/person/year.

Regarding trade openness, Singapore has the highest trade openness, reaching an average of 339.44% of GDP and once reached the highest level of 437.32% of GDP. Vietnam and Malaysia have quite high levels of openness, reaching an average of 111.58% of GDP

and 142.23% of GDP, respectively, while Thailand, the Philippines, and Indonesia have lower levels of trade openness. Further, Laos has the lowest openness, at only about 63.22% of GDP.

**Table 2.** Descriptive statistics by country.

| Country | Item | REC | FI | GDP | TRADE | FDI | HUMAN |
|---|---|---|---|---|---|---|---|
| Indonesia | Mean | 40.2629 | 35.00041 | 1473.123 | 49.92636 | 1.236033 | 108.0276 |
| | Std. Dev. | 11.39554 | 13.81533 | 1422.894 | 11.0233 | 1.289745 | 10.49208 |
| | Min | 19.77 | 9.610778 | 78.86576 | 28.68263 | −2.75744 | 84.48063 |
| | Max | 59.18 | 59.86041 | 4787.999 | 96.18619 | 4.241289 | 122.7521 |
| Laos | Mean | 71.01406 | 17.79672 | 959.7189 | 63.22765 | 3.612838 | 102.7089 |
| | Std. Dev. | 14.15205 | 7.071894 | 867.8228 | 25.08238 | 2.8412 | 14.88087 |
| | Min | 48.72 | 7.10931 | 146.9858 | 9.105691 | −0.0684507 | 57.41764 |
| | Max | 88.4 | 36.18783 | 2598.506 | 99.05974 | 9.917783 | 121.5094 |
| Malaysia | Mean | 4.416129 | 108.895 | 4858.497 | 142.2376 | 3.695033 | 99.91026 |
| | Std. Dev. | 1.731985 | 29.57733 | 3687.528 | 41.89753 | 1.711019 | 2.334718 |
| | Min | 1.96 | 40.90456 | 374.9229 | 73.37553 | 0.0566923 | 91.99315 |
| | Max | 8.42 | 140.7617 | 11971.93 | 220.4068 | 8.760474 | 102.7615 |
| Philippines | Mean | 34.42968 | 45.12058 | 1401.004 | 60.25274 | 1.231243 | 105.7755 |
| | Std. Dev. | 6.178968 | 21.58527 | 1008.913 | 17.37069 | 0.911827 | 4.728412 |
| | Min | 26.8 | 17.26252 | 201.9233 | 32.18014 | −0.2876676 | 90.60991 |
| | Max | 51.05 | 90.49053 | 3498.51 | 87.57464 | 3.122388 | 112.2945 |
| Singapore | Mean | 0.5441935 | 93.15777 | 26,374.46 | 339.44 | 14.18878 | 101.6246 |
| | Std. Dev. | 0.1458943 | 26.60855 | 23,200.52 | 43.04756 | 7.927348 | 1.316913 |
| | Min | 0.19 | 53.96138 | 925.7979 | 229.0534 | 3.646085 | 99.87465 |
| | Max | 0.92 | 148.9482 | 82,807.65 | 437.3267 | 32.69117 | 103.5642 |
| Thailand | Mean | 23.16258 | 86.9229 | 2757.03 | 88.68364 | 1.889597 | 99.38834 |
| | Std. Dev. | 3.539984 | 34.96454 | 2300.729 | 36.25757 | 1.46938 | 7.807945 |
| | Min | 19.89 | 32.04237 | 197.9937 | 34.40231 | −0.9885908 | 81.25114 |
| | Max | 33.51 | 148.8354 | 7628.576 | 140.437 | 6.434807 | 108.6956 |
| Vietnam | Mean | 47.3971 | 74.04713 | 1279.998 | 111.5871 | 4.747831 | 109.2521 |
| | Std. Dev. | 16.89662 | 34.95285 | 1263.99 | 42.49663 | 2.797217 | 7.113623 |
| | Min | 19.11 | 19.56649 | 96.13036 | 18.95049 | −0.0005676 | 97.41997 |
| | Max | 75.91 | 127.2349 | 4163.514 | 186.4682 | 11.93948 | 125.0868 |

*Source: Authors' analysis.*

Regarding FDI, Singapore is considered to have the ability to attract a high rate of FDI, followed by Vietnam and Malaysia, while the Philippines and Laos have not really succeeded. In general, countries with high FDI often have high economic openness, which helps the country attract investment capital flows to serve foreign trade activities and vice versa.

Table 3 shows the results of the correlation analysis of variables used in the regression model. The results of correlation analysis show that independent variables have a low correlation level, so multicollinearity is unlikely to occur. Similarly, to confirm this based on VIF analysis in Table 4, this ratio is less than 10; therefore, multicollinearity is unlikely to occur.

**Table 3.** Correlation matrix.

| | REC | FI | GDP | TRADE | FDI | HUMAN |
|---|---|---|---|---|---|---|
| REC | 1.0000 | | | | | |
| FI | −0.5595 | 1.0000 | | | | |
| GDP | 0.5474 | −0.5561 | 1.0000 | | | |
| TRADE | 0.3853 | −0.4761 | 0.8981 | 1.0000 | | |
| FDI | 0.4778 | −0.4351 | 0.5939 | 0.4904 | 1.0000 | |
| HUMAN | 0.4052 | −0.4536 | 0.8845 | 0.9182 | 0.4774 | 1.0000 |

*Source: Authors' analysis.*

**Table 4.** VIF analysis.

| Variable | VIF | 1/VIF |
|---|---|---|
| TRADE | 7.91 | 0.126426 |
| FI | 6.20 | 0.161251 |
| FDI | 5.05 | 0.198121 |
| GDP | 3.92 | 0.255358 |
| HUMAN | 1.44 | 0.693905 |
| Mean VIF | 4.90 | |

*Source: Authors' analysis.*

Table 5 shows the regression results for Equation (1), and Table 6 shows the regression results for Equation (2) based on ordinary least squares (OLS), fixed effects method (FEM), and random effects method (FEM). In the case of diagnostics issues, the feasible generalized least squares (FGLS) should be performed. In addition, Table 7 shows the robustness test. We obtained the following results:

**Table 5.** Regression results for financial development FI.

| Variable | OLS | FEM | REM | FGLS |
|---|---|---|---|---|
| FI | −0.2045 ***<br>(0.000) | 0.0364<br>(0.230) | 0.0198<br>(0.516) | −0.2045 ***<br>(0.000) |
| GDP | −28.1583 ***<br>(0.000) | −26.3752 ***<br>(0.000) | −25.7075 ***<br>(0.000) | −28.1583 ***<br>(0.000) |
| TRADE | −0.0174<br>(0.492) | −0.1195 ***<br>(0.000) | −0.1029 ***<br>(0.000) | −0.0174<br>(0.484) |
| FDI | 0.9913 ***<br>(0.001) | −0.1742<br>(0.343) | −0.0518<br>(0.775) | 0.9913 ***<br>(0.000) |
| HUMAN | 0.0780<br>(0.547) | 0.1483 **<br>(0.041) | 0.1270 *<br>(0.081) | 0.0780<br>(0.539) |
| _cons | 132.5722 ***<br>(0.000) | 117.487 ***<br>(0.000) | 119.7366 ***<br>(0.000) | 132.5722 ***<br>(0.000) |
| Prob > F | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| R-squared | 0.8649 | 0.6776 | 0.7080 | |
| F test | F(6, 16) = 92.47<br>Prob > F = 0.0000 | | | |
| Hausman test | Chi2(5) = 2.83<br>Prob > chi2 = 0.7257 | | | |

*Note: ***, **, and *, respectively, indicate the significant level of 1%, 5%, and 10%. Source: Authors' analysis.*

**Table 6.** Regression results for financial development CD.

| Variable | OLS | FEM | REM | FGLS |
|---|---|---|---|---|
| DC | −0.1389 ***<br>(0.000) | −0.0321<br>(0.131) | −0.0376<br>(0.077) | −0.1389 ***<br>(0.000) |
| GDP | −31.2066 ***<br>(0.000) | −24.1807 ***<br>(0.000) | −24.0037 ***<br>(0.000) | −31.2066 ***<br>(0.000) |
| TRADE | −0.0481 **<br>(0.031) | −0.0976 ***<br>(0.000) | −0.0879 ***<br>(0.000) | −0.0481 **<br>(0.027) |
| FDI | 1.3841 ***<br>(0.000) | −0.2335<br>(0.191) | −0.1210<br>(0.485) | 1.3841 ***<br>(0.000) |
| HUMAN | 0.0398<br>(0.765) | 0.0966<br>(0.190) | 0.0805<br>(0.275) | 0.0398<br>(0.761) |
| _cons | 142.4524 ***<br>(0.000) | 118.3083 ***<br>(0.000) | 119.7366 ***<br>(0.000) | 142.4524 ***<br>(0.000) |
| Prob > F | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| R-squared | 0.8673 | 0.7149 | 0.7357 | |
| F test | F(6, 16) = 94.31<br>Prob > F = 0.0000 | | | |
| Hausman test | Chi2(5) = 4.89<br>Prob > chi2 | | | |

*Note: *** and **, respectively, indicate the significant level of 1% and 5%. Source: Authors' analysis.*

**Table 7.** Regression results for the robustness check.

| Variable | Driscoll–Kraay Standard Errors | DOLS |
|---|---|---|
| FI | −0.2045 ***<br>(0.011) | −0.1847 ***<br>(0.000) |
| GDP | −28.1583 ***<br>(0.000) | −46.4692 ***<br>(0.000) |
| TRADE | −0.0174<br>(0.431) | −0.4336 ***<br>(0.000) |
| FDI | 0.9913 ***<br>(0.000) | 2.4060 ***<br>(0.000) |
| HUMAN | 0.0780<br>(0.693) | 0.8560 ***<br>(0.000) |
| _cons | 132.5722 ***<br>(0.000) | |
| Prob > F | 0.0000 | 0.0000 |
| R-squared | 0.8687 | 0.9626 |

*Note: *** is the significant level of 1%. Source: Authors' analysis.*

The regression coefficient of FI is negative and statistically significant. That is, financial development has a negative impact on renewable energy consumption. It can also be explained that the country has increased its financial development but has not changed renewable energy consumption. It can be understood that the financial market has not really oriented capital flows into renewable energy development, or the financial market still seems to be oriented toward fossil energy consumption and production that do not yet exist based on high-tech properties. This research result is similar to the observation of Li and Shao (2023), confirming that financial market development can expand renewable energy industries, but renewable energy innovation gradually decreases, similar to another study by Li et al. (2022), indicating that with high economic development, there will

be more investment resources for renewable energy to meet energy demand. However, fossil energy sources are still becoming important due to their low cost and ability to meet increased energy consumption needs, so it takes time for the economy to be able to innovate its growth model through technology investment, clean energy consumption, and knowledge-intensive production. Further on this relationship, it can be explained that renewable energy sources cannot yet contribute a larger role to energy demand in Southeast Asia. Table 1 shows that the contribution of renewable energy to the total energy demand in selected Southeast Asian countries has decreased continuously since 1990, even though renewable energy is used very little in Malaysia and Singapore, thereby confirming that most of the energy in Malaysia and Singapore comes from fossil energy. The country with the largest renewable energy use is Laos, which also had a sharp decline and currently only maintains about 49.91% of total energy demand. Nguyen and Nguyen (2021) also believed that countries should have a strategy to promote the contribution of renewable energy to the total energy demand and therefore promote green growth. Indeed, green growth strategies can help countries optimize their production by reducing environmental costs and promoting sustainable development. In fact, economic development leads to negative impacts on the environment; it can increase social costs on the economy and human health through medical costs and reduce social welfare. According to the goals of COP, especially the recent COP28, it is suggested that the loss and damage funds should be maintained to support financial resources for vulnerable countries to help them be able to respond to climate change and reduce environmental pollution. However, it is evident that the monitoring mechanism in vulnerable countries to improve the effectiveness of this financial resource is extremely important. Empirical evidence shows that when the financial market develops, it is not necessarily effective for renewable energy, but on the contrary, the economy still depends on fossil energy. In fact, when the financial market has not yet directed financial resources into technology investment projects or less energy consumption, it is very difficult to improve production and consumption associated with environmental protection and sustainable development. Therefore, the effectiveness of COP implementation must be associated with constraints on using financial resources in cleaner production and overcoming negative impacts on the environment to bring efficiency to the economy.

The regression coefficient of GDP has a negative sign and is statistically significant. That is, when per capita income increases, it has a negative effect on renewable energy consumption. This evidence can be explained as follows: when per capita income increases, energy consumption demand increases, and to meet increased energy consumption, countries promote investment in energy sources, especially in fossil energy sources. Indeed, renewable energy sources have increased in Southeast Asian countries recently, but this increase has not been able to meet energy consumption needs, and therefore fossil energy sources still play a huge role in ensuring energy needs. Figure 1 shows that Singapore uses nearly 100% fossil energy, while other countries such as Vietnam, Thailand, and Malaysia consume renewable energy to meet their total energy demand, which tends to decrease. This reflects that renewable energy does not meet short-term energy needs. This result raises the challenge of achieving the 2050 net zero emissions target proposed in COP26. Indeed, Southeast Asian countries have high levels of economic growth and high energy consumption needs, while renewable energy resources in this region are still limited and have not been fully exploited. To achieve the COP26 goal, Southeast Asian countries need to transform their growth model in the direction of saving energy sources, emitting less carbon emissions in the environment, and increasing green production and consumption.

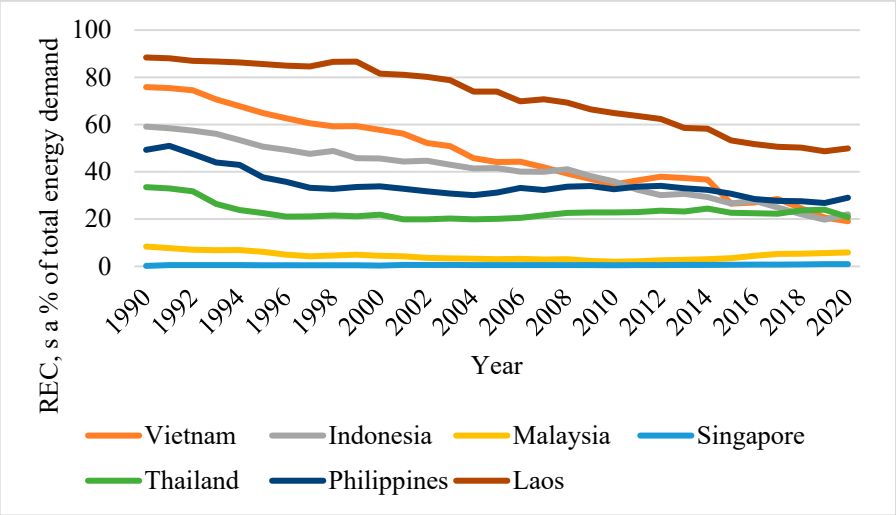


**Figure 1. REC of selected Southeast Asian economies (% total energy demand).** Source: World Bank Development Indicators.

The research results show that there is no clear relationship between trade openness and human capital and renewable energy consumption. This result is different from the study by Qamruzzaman and Wei (2020), who found that there are benefits of economic integration in renewable energy consumption. However, there is no clear evidence in Southeast Asia. This region is heavily impacted by the rapid increase in annual energy demand, and renewable energy sources have not been invested in much to be able to meet the region's overall energy consumption needs. However, there is a positive influence between attracting foreign direct investment and renewable energy. This shows the benefits of attracting FDI capital flows and investing this capital flow in renewable energy. Second, FDI projects have a higher technological content than domestic ones, so FDI projects consume less energy and therefore have less of impact on the environment than domestic projects. This research result is supported by Doytch and Narayan (2016), who believe that FDI is a source of investment capital that enhances the development of renewable energy and non-renewable energy. However, using renewable energy is a future development trend because this energy source has little social cost and helps sustainable development.

## 5. Conclusions

Socio-economic development leads to an increased demand for energy consumption and has a negative impact on the environment and quality of life. Renewable energy is indispensable to meet energy needs, and using this energy source especially has the ability to reduce negative impacts on the environment and enable sustainable economic development. Therefore, the financial market always plays an important role in the process of allocating capital in the economy, especially allocating capital to projects aimed at reducing carbon emissions and investing in renewable energy. The objectives of this study are to assess the role of financial development on renewable energy consumption in selected Southeast Asia regions through quantitative analysis. We used the Driscoll–Kraay standard errors to assess cross-dependence between countries in the region as well as the Dynamic Ordinary Least Squares Estimator (DOLS) analysis to evaluate the robustness of this study; the results show that financial development has a negative impact on renewable energy consumption, the same evidence when per capita income increases. This study also confirms the positive impact of foreign direct investment on renewable energy use. In addition, there is no clear relationship between trade openness and human capital and renewable energy consumption. However, there exists a positive impact between attracting foreign direct investment and renewable energy consumption in the case of selected Southeast Asian countries.

This study has several policy implications for Southeast Asian countries. Firstly, Southeast Asian countries should improve their financial markets to operate more effectively through resource allocation policies oriented toward increasing financial resources for projects with high technology content and gradually reducing projects with high energy consumption and environmental pollution. Secondly, countries should increase the attraction of FDI capital flows with high scientific and technological content and FDI capital flows investing in green energy development to increase the contribution to the domestic energy demand.

There are several limitations that exist in this study and are suggestions for future research. Firstly, this study has not evaluated the impact of external shocks on the relationship between financial development and renewable energy consumption, especially the effects of the Asian financial crisis and the COVID-19 pandemic, as well as other influences. Secondly, this research has not evaluated the specificities of each country to clarify the impact of financial development on renewable energy consumption for different economies with different specific characteristics. Thirdly, this research has not evaluated other factors, such as institutional quality, geographical location, and internal problems in the economy.

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