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How Does the Endogeneity of Energy Financing, Carbon Emissions, and Energy Transition Affect the Upper-Middle-Income Countries in ASEAN?

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ABSTRACT

This study examines the endogeneity between energy financing, carbon emissions, and energy transition in Indonesia, Malaysia, and Thailand as upper-middle-income countries in ASEAN. Using data from 2000 to 2023, it analyzes the interactions among these three variables through a Vector Autoregression (VAR) approach. The study plays an essential role in highlighting the complex relationships among these variables, which often impact both economic dynamics and environmental sustainability. The findings show that no causal relationships exist between the variables. However, there is a one-way effect, where carbon emissions and energy intensity significantly influence energy financing, and energy intensity also has a significant impact on carbon emissions. These findings suggest that, despite the absence of causal relationships, increases in energy intensity and carbon emissions may drive higher energy financing. The policy implications underscore the importance of government roles in upper-middle-income ASEAN countries to enhance incentives for renewable energy investment, promoting energy intensity to help curb carbon emissions. Additionally, governments need to allocate more energy financing toward clean energy projects that can reduce the accumulation of carbon emissions. Such policies are expected to foster a more sustainable energy transition and contribute to lowering carbon emissions in ASEAN's upper-middle-income countries.

Keywords: Carbon Emissions, Energy Financing, Energy Transition, Vector Autoregression
JEL Classifications: Q42, Q43, Q54, Q56.

1. INTRODUCTION

Amid the increasingly concerning dynamics of global climate change, energy and environmental research has become more crucial (Kurniadi et al., 2021; Sueyoshi et al., 2017). Carbon emissions (CE), as one of the indicators for assessing environmental conditions, if left uncontrolled, could lead to significant global warming and an environmental crisis due to the role of energy as a key driver of economic growth (Liu and Bae, 2018; Shahbaz et al., 2017; Smith and Myers, 2018). The rising air pollution, ecosystem damage, and threats to the sustainability of natural resources have been caused by a high dependence on fossil energy sources (Zhukovskiy et al., 2021). Imbalances in the management of the energy sector can exacerbate these negative impacts, including more frequent natural disasters, disruptions to human quality of life, and long-term declines in economic productivity (Aimon et al., 2021; Baz et al., 2021; Kurniadi et al., 2022).

The phenomenon of energy financing (EF), CE, and energy transition (ET) has become increasingly important in ASEAN, particularly in upper-middle-income countries (UMIC) like Indonesia, Malaysia, and Thailand. EF, CE, and ET are interconnected and form a dynamic pattern that shapes the path toward sustainable energy policies (Alola and Joshua, 2020; Chien et al., 2023). These countries are experiencing rapid economic growth, making it difficult to formulate policies that can drive a shift toward renewable energy and away from fossil fuels (Aimon et al., 2023a; Nguyen and Nguyen, 2018). Although there is growing awareness that ET is essential for mitigating climate change, the biggest challenge lies in the EF required to support ET (Steffen, 2018). Developing renewable energy sources is often hindered by a heavy reliance on fossil fuels and the need to maintain an affordable and reliable energy supply (Hall et al., 2017).

The majority of EF in Indonesia, Malaysia, and Thailand through 2023 has been dominated by investments in fossil fuels such as coal, oil, and natural gas (Hossin et al., 2024). According to the International Energy Agency (2023), around 60-70% of total energy investments in ASEAN are allocated to the fossil fuel sector, with Indonesia being one of the world's leading coal exporters. Data from the Institute for Energy Economics and Financial Analysis (2023) also shows that between 2021 and 2022, more than USD 12 billion in energy financing in the region was concentrated in fossil fuel-based power generation projects. Meanwhile, investments in renewable energy such as solar and wind power are still significantly behind. In Indonesia, despite the target to increase renewable energy capacity by 23% by 2025, the actual achievement was only about 12% in 2023, according to the Ministry of Energy and Mineral Resources (2023). Malaysia and Thailand also face similar challenges, with renewable energy penetration stagnating at 18% and 20% in 2023, based on data from the Renewable Energy Policy Network (2023). This situation is exacerbated by the lack of adoption of advanced technologies in renewable energy and the limited fiscal and non-fiscal incentives provided to encourage the green energy sector. For example, World Bank (2022) noted that tax incentives for renewable energy in Indonesia cover only a small portion of the projected investment needs, which are estimated to reach USD 150 billion by 2030. As a result of the slow transition to renewable energy, CE in these countries continue to rise. Additionally, Indonesia's carbon emissions reached 625 million tons of CO_2 in 2021 and increased to 640 million tons of CO_2 in 2023, with the majority coming from the energy sector Climate Watch (2023). Meanwhile, Thailand and Malaysia reported similar figures, each with carbon emissions exceeding 300 million tons of CO_2 in 2023 (Climate Watch, 2023).

There is ongoing debate among academics and policymakers regarding the dynamics of EF, CE, and ET. Some believe that allocating a larger EF to renewable energy could help accelerate the reduction of CE (Egli et al., 2018; Qadir et al., 2021; Rasoulinezhad and Taghizadeh-Hesary, 2022). Various studies have found that ET requires time and long-term investment, which may not always align with short-term economic needs, especially in developing countries with limited budgets (Aimon et al., 2022; Narváez, 2019). Additionally, reliance on fossil fuels poses a significant barrier, as the shift to renewable energy is often accompanied by technical challenges, inadequate infrastructure, and social resistance to major changes in the energy industry (Aimon et al., 2023b; Kurniadi et al., 2024).

Previous research on the endogeneity between EF, CE, and ET highlights both benefits and drawbacks, illustrating the complexity of the relationship among these factors. On one hand, many studies support the idea that increasing EF, particularly when allocated to renewable energy sources, has great potential to reduce CE (Acheampong et al., 2020; Meo and Abd Karim, 2022; Ren et al., 2020). This argument is based on the fact that investment in clean energy technologies can reduce reliance on fossil fuels and promote the development of more environmentally friendly infrastructure. Moreover, investment in the renewable energy sector has the potential to create new jobs, enhance national energy security, and accelerate the achievement of sustainable development goals. Furthermore, other studies have also found that the more EF allocated to renewable energy, the greater the likelihood of reducing CE (Adams and Acheampong, 2019; Akadiri and Adebayo, 2022; Jiang and Ma, 2019). This is because technologies such as solar panels, wind, and biomass have much lower emissions compared to fossil fuels.

On the other hand, some other studies challenge this idea, arguing that an increase in EF does not always correlate with a reduction in CE (Khan et al., 2021; Lei et al., 2022; Saqib, 2022). Their studies show that before a more sustainable ET is achieved, increased investment in the energy sector may actually worsen CE in countries that heavily rely on coal. This is because, during the transition phase, significant investments in new energy technologies are often not matched by a substantial reduction in the amount of fossil fuels used, leading to an increase in CE in the short term. In fact, an increase in EF in the renewable energy sector may sometimes only accelerate decarbonization once the necessary infrastructure is fully available and mature (Rahman and Alam, 2022). This debate centers on the imbalance in ET and the prolonged dependence on fossil fuel sources in the short term.

In addition, findings from other studies emphasize that local context is crucial in determining the effectiveness of EF (Cloke et al., 2017; Geddes et al., 2018; Rand and Hoen, 2017). The economic structure and energy characteristics of each country differ. For example, Indonesia, Malaysia, and Thailand are highly dependent on both renewable and fossil energy. Therefore, the same EF policies and strategies may not always be implemented in the same way. In certain situations, these countries may face greater difficulties in integrating renewable energy into their systems, which are still reliant on fossil fuels. Additionally, there are concerns about the imbalance between socio-economic needs and investments in renewable energy; this may make cheaper and more accessible energy a top priority in the short term, even if it results in increased CE.

Based on the explanation above, the purpose of this study is to examine how EF, CE, and ET are interrelated in countries within the ASEAN UMIC, consisting of Indonesia, Malaysia, and Thailand. The urgency of this research is to gain a better understanding of how these three factors interact with each other in the formulation of sustainable energy policies. By analyzing empirical data, this study will also provide insights into policies that can optimize EF, reduce CE, and accelerate ET.

2. LITERATURE REVIEW

Numerous empirical studies have been conducted to understand the relationship between EF, CE, and ET. These studies highlight the importance of understanding the causality among these variables to support sustainable ET. One key finding is that EF plays a significant role in accelerating ET in developing countries. Sovacool and Griffiths (2020) found that the adoption of low-carbon technologies can be expedited through fiscal incentives such as renewable energy subsidies or tax reductions for green investments. They also emphasized that the availability of technology and effective financing structures are critical in the ET process.

Research on the relationship between EF and ET often involves the growth of financial markets. Tan et al. (2020) highlighted a bidirectional relationship between financial markets and EF. Investments in green technology not only drive innovation in the financial sector, such as the issuance of green bonds, but also create opportunities for financial markets to support more clean energy projects. Additionally, Carley and Konisky (2020) concluded that easy access to EF could accelerate ET, particularly in countries with developing financial markets.

Other studies, such as Habiba et al. (2022) identified that a country's level of economic development influences the effectiveness of EF in reducing CE. Developed countries are better positioned to utilize EF due to their technological advancements, stricter regulations, and higher public awareness of environmental issues. Their research also revealed short-term challenges, as increased EF often occurs in nations heavily dependent on fossil fuels.

Similarly, Pala (2020), using cointegration and causality analysis, investigated the relationship between CE, economic growth, and EF in G20 countries. They found that EF significantly reduces CE while supporting sustainable economic growth, especially in countries with strong climate policy commitments. Waheed et al. (2019) also observed that EF is beginning to have a significant impact on CE reduction in African countries, though its effectiveness depends on reaching certain thresholds.

Further research by Sadiq et al. (2022) showed that while EF significantly influences CE reduction, its impact is often shaped by policy changes and energy market dynamics. They emphasized that although EF relies on consistent policy support, it still drives low-carbon technology development. Meanwhile, Schwerhoff and Sy (2017) revealed that developing countries often struggle to utilize EF effectively due to limited access to capital and technology.

On a broader scale, studies by Ouedraogo (2019) and Zeng et al. (2017) indicated that countries with underdeveloped renewable energy infrastructure or weak public policies may face challenges in implementing effective EF. Saidi and Omri (2020) noted that while initial investments in renewable energy can lay the foundation for long-term benefits, their impact on CE reduction is often not immediate. In contrast, Qadir et al. (2021) found that countries with public policies supporting EF are more successful in reducing CE and promoting ET.

Overall, prior research underscores the importance of a multidimensional approach to understanding the complex and endogenous relationship between EF, CE, and ET. Previous studies employed various theoretical and methodological frameworks to provide insights that could guide policymakers in crafting policies to support sustainable ET and global CE reduction. This study offers a new contribution by examining the endogeneity between EF, CE, and ET in ASEAN UMIC, which face unique challenges related to technological access and dependence on fossil fuels. The focus of this study distinguishes it from earlier research, which predominantly centers on developed countries or global contexts. By utilizing an endogeneity analysis methodology, this research aims to capture the bidirectional causality among these variables. This approach is expected to provide fresh insights into energy and environmental dynamics in ASEAN UMIC and offer relevant policy recommendations.

3. METHODOLOGY AND DATA

3.1. Data and Variables

This study employs panel secondary data, combining time series and cross-sectional data. The time series data spans from 2000 to 2023, while the cross-sectional data focuses on three ASEAN UMIC: Indonesia, Malaysia, and Thailand. This approach facilitates the analysis of long-term dynamics and the comparison of these three countries' developments in the economic and energy contexts. Then, all variables in this study are endogenous, meaning they mutually influence and are closely interrelated within the analyzed system. The three main variables examined are EF, CE, and ET, as depicted in Figure 1.

Figure 1 illustrates the research framework, providing clear direction and purpose regarding the relationships among the variables studied. However, without precise indicators, the measurement of these variables may become ambiguous or inconsistent. Effective indicators should capture the dimensions or aspects intended for analysis, as outlined in Table 1.

3.2. Analytical Model

The analytical model in this study was developed based on the relationships among variables identified in Figure 1. The figure illustrates the interconnections and mutual influences among various relevant variables within the context of this research. Based on these relationships, the analytical model was constructed by formulating three interrelated equations, including:

$$EF_{it} = \alpha_{01i} + \sum_{j=1}^{p} \beta_{01i} EF_{i,t-j} + \sum_{j=1}^{p} \gamma_{01i} CE_{i,t-j} + \sum_{j=1}^{p} \sigma_{01i} ET_{i,t-j} + \varepsilon_{01t} \quad (1)$$

$$CE_{it} = \alpha_{02i} + \sum_{j=1}^{p} \beta_{02i} EF_{i,t-j} + \sum_{j=1}^{p} \gamma_{02i} + \sum_{j=1}^{p} \sigma_{02i} ET_{i,t-j} + \varepsilon_{02t} \quad (2)$$

Figure 1: Research framework

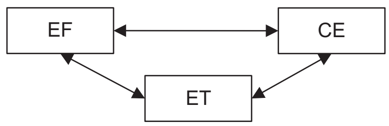


Table 1: Variable indicators

Variable	Description
EF	International funding for developing countries to support clean energy research and renewable energy production, expressed in US dollars.
CE	Accumulated carbon emissions, measured in megatons of carbon dioxide (Mt CO_2).
ET	Contribution of renewable energy sources to the total energy mix, expressed as a percentage.

$$ET_{it} = \alpha_{03i} + \sum_{j=1}^{p} \beta_{03i} EF_{i,t-j} + \sum_{j=1}^{p} \gamma_{03i} CE_{i,t-j} + \sum_{j=1}^{p} \sigma_{03i} ET_{i,t-j} + \varepsilon_{03t} \tag{3}$$

Notation explanation:
t: Time period
i: Cross-section unit
i, t-j: Lagged value of the variable
α: Constant term
β, γ, σ: Coefficients
p: Number of lags
ε: Residual term

3.3. Data Analysis Techniques

This study employs the Vector Autoregression (VAR) approach, encompassing several stages of analysis. First, stationarity tests are conducted using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to ensure that the data do not exhibit trends or fluctuations that could affect the results. Next, an optimal lag test is performed to determine the appropriate lag length for the model by considering the values of the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), and Schwarz Criterion (SC).

Subsequently, a stability test is conducted to ensure that the VAR model remains consistent and valid. The cointegration test identifies long-term relationships among the variables analyzed. Following this, the Granger causality test is used to uncover the direction of causal relationships between variables. The Impulse Response Function (IRF) evaluates the response of variables to shocks, while Variance Decomposition (VD) analyzes the contribution of each variable to the model's variance. These steps enable a comprehensive analysis of the interrelationships among variables within the model.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistical Analysis

Descriptive statistical analysis plays a crucial role in understanding data and presenting information in a concise and meaningful way.

Table 2: Descriptive statistics of research variables

Data description	Variable		
	EF	CE	ET
Mean	135.299.726	279	12
Standard deviation	235.449.830	121	5
Skewness	2.38	1.08	0.36

Table 3: Stationarity test results

Variable	Level I (0)		1st Difference I (1)	
	ADF	PP	ADF	PP
EF	0.0081***	0.0011***	-	-
CE	0.9513	0.5426	0.0002***	0.0000***
ET	0.9999	0.9997	0.0079***	0.0000***

***Significant at α=1%

Through the descriptive statistics in Table 2, the key characteristics of the dataset under study can be identified, providing initial insights into patterns, variation, and data distribution.

Based on the information presented in Table 2, EF has an average of 135,299,726 USD with a standard deviation of 235,449,830 USD, indicating significant variation in the EF data. A skewness value of 2.38 suggests a right-skewed distribution, indicating the presence of some high extreme values in EF. For CE, the average is 279 Mt CO_2 with a standard deviation of 121 Mt CO_2, showing considerable fluctuations among the observed CE data. A skewness of 1.08 indicates a right-skewed distribution, though less pronounced compared to EF. Lastly, ET has an average of 12% with a standard deviation of 5%. Its low skewness of 0.36 indicates a relatively symmetric distribution, suggesting that ET values are generally centered around the mean without any prominent skewness. Overall, this descriptive statistical analysis provides essential preliminary insights into the dynamics of EF, CE, and ET.

4.2. Stationarity Test Results

The stationarity test in Table 3 is a crucial step in the VAR analysis, as it helps ensure that the data used in the model do not contain trends or patterns that could undermine the validity of the analysis results. Stationary data tend to have a constant mean and variance over time, making them more reliable for predicting relationships between variables.

Based on the results of the stationarity test presented in Table 3, it can be seen that for EF, the ADF and PP values at the level indicate highly significant probabilities, suggesting that EF is stationary at I(0). In contrast, for CE and ET, the ADF and PP values show that these two variables are not stationary at I(0). However, when examined at I(1), the ADF and PP values for CE and ET become significant. This indicates that after I(1), both CE and ET become stationary.

4.3. Optimal Lag Test Results

The selection of the optimal lag is a crucial step in VAR analysis because the correct lag can improve the accuracy of the model and provide more informative results. By determining the optimal

Table 4: Optimal lag test results

Lag	LogR	LR	FPE	AIC	SC	HQ
0	−164.1837	NA	0.141226	6.556223	6.669860	6.599647
1	−132.1303	59.07880*	0.057240*	5.652169*	6.106716*	5.825865*
2	−123.6577	14.61942	0.058686	5.672850	6.468308	5.976818
3	−119.0125	7.468713	0.070329	5.843628	6.979996	6.277867
4	−114.1636	7.225795	0.084354	6.006416	7.483695	6.570928
5	−105.2444	12.24205	0.087303	6.009585	7.827774	6.704368
6	−96.11251	11.45965	0.091060	6.004412	8.163511	6.829468

Table 5: Stability test results

Root	Modulus
0.763465	0.763465
0.068826−0.021562i	0.072125
0.068826+0.021562i	0.072125

lag, the data can be optimally utilized to produce more accurate and reliable analysis, as shown in Table 4.

Based on the information in Table 4, the optimal lag for the VAR model in this study is 1, where the model shows the best performance with the highest LR value and the lowest information criteria values (FPE, AIC, SC, and HQ). Determining the optimal lag is crucial to ensure that the VAR model provides valid and relevant estimates of the relationships between the variables under investigation.

4.4. Stability Test Results

The stability test in Table 5 and Figure 2 is an important step to ensure that the model used exhibits stable dynamic behavior. A stable model indicates that, after experiencing shocks, the system will return to its equilibrium state or move toward long-term stability. This is crucial for maintaining the reliability of the projections or interpretations derived from the model.

Based on the stability test results presented in Table 5 and Figure 2, all root values have a modulus of <1. This indicates that the model meets the stability criteria, with the highest root value being 0.763465. Additionally, there are two complex roots with a modulus of 0.072125.

Figure 2 illustrates that the inverse roots of the AR polynomial lie within the unit circle. Overall, these results indicate that the model in this study is stable and reliable in generating projections that are neither explosive nor deviate from equilibrium conditions in the long run.

4.5. Cointegration Test Results

The cointegration test in Table 6 is crucial in VAR analysis for panel data, especially to assess whether there is a long-term relationship between the analyzed variables. The presence of cointegration ensures that, despite short-term fluctuations, the variables tend to move together in the long run. If the test results indicate cointegration, the analysis must proceed with a VAR model that accounts for the long-term relationships between variables.

Table 6: Cointegration test results

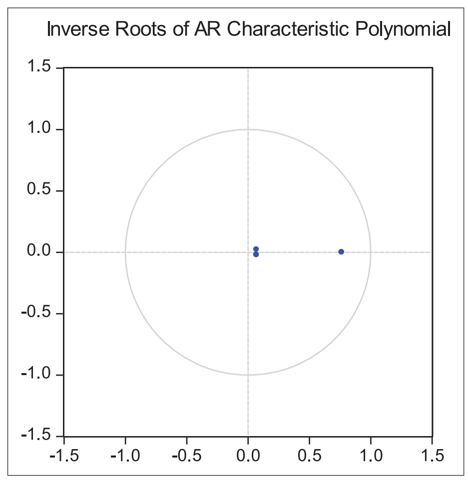
Panel cointegration test	Statistic	P	Weighted statistic	P
Panel v-Statistic	−0.029106	0.5116	−0.676636	0.7507
Panel rho-Statistic	−1.163577	0.1017	−0.905631	0.1826
Panel ADF-Statistic	−1.105296	0.1345	−0.443540	0.3287

Table 7: Granger causality test results

Null hypothesis:	Obs	F-Statistic	P
CE does not granger cause EF	69	13.0023	0.0006***
EF does not granger cause CE		0.07078	0.7910
ET does not granger cause EF	69	2.84468	0.0964*
EF does not granger cause ET		0.01142	0.9152
ET does not granger cause CE	69	6.16576	0.0156**
CE does not granger cause ET		1.77826	0.1869

**Significant at α=5% and *at α=10%

Figure 2: Stability graph



Based on the results in Table 6, the cointegration test shows that the Panel v-Statistic, Panel rho-Statistic, and Panel ADF-Statistic are not significant, for both weighted and unweighted statistics. This indicates that there is no cointegration between the variables in this model. In other words, there is insufficient statistical evidence to conclude the presence of a long-term relationship among the variables in the tested model.

4.6. Granger Causality Test Results

The Granger causality test plays a significant role in understanding the cause-and-effect relationship between variables. This test identifies whether one variable influences another, as shown in Table 7.

First, no bidirectional causality between CE and EF was found in the ASEAN UMIC—Indonesia, Malaysia, and Thailand. This means that variations in EF levels do not directly influence changes in CE in these countries, and vice versa. However, a unidirectional relationship was found where CE significantly influences EF, with a probability of 0.0006, which is well below the 1% significance level. This result suggests that increasing CE acts as a driver or trigger for these three countries to boost investment and funding in the energy sector. In terms of policy, this finding indicates that the continuous rise in CE puts pressure on policymakers and financial institutions to allocate more resources to the energy sector. This allocation may be directed towards the development of clean energy or more environmentally friendly technologies to reduce negative environmental impacts and meet CE reduction commitments. As rapidly developing economies, Indonesia, Malaysia, and Thailand may recognize that their reliance on fossil fuels will exacerbate CE, making EF a priority to support the transition to renewable energy. This finding highlights the role of CE as a driving factor for more proactive and sustainable energy policies in the ASEAN UMIC, aimed at achieving balanced economic growth alongside environmental commitments. This research is supported by Xu and Wu (2023), who identified a similar pattern in developing countries, where rising CE significantly drives an increase in renewable EF as a response to the need for CE reduction and efforts to achieve long-term sustainability targets. Additionally, De Haas and Popov (2019) found that in developing countries, high CE motivates larger allocations of funds to the renewable energy sector as a step towards reducing dependence on fossil fuels and mitigating environmental damage. Furthermore, Ren et al. (2020) conducted a study on several developing countries, showing that CE pressure encourages energy financing for sustainable projects. This result illustrates that as CE increases, these countries begin allocating more investment to the energy sector to develop cleaner and more sustainable energy. Thus, this study supports the idea that CE can be a major driver for EF, particularly in efforts to reduce CE through clean energy, in line with global goals for sustainable development.

Second, no bidirectional causality between ET and EF was found in the ASEAN UMIC—Indonesia, Malaysia, and Thailand. The results of the study indicate a unidirectional relationship, with ET potentially influencing EF, as the probability value of 0.0964 is below the 10% significance level. This suggests that ET initiatives, such as the shift from fossil fuels to cleaner energy sources, encourage governments and financial institutions to increase EF in order to support the success of the transition. In terms of policy, these findings suggest that the decision to undertake ET becomes a significant factor in determining EF. However, the probability slightly above the 5% significance level indicates that the relationship is not strong enough to be considered significant at the conventional level. This suggests that while ET has an effect on EF, this influence may be weaker or dependent on specific conditions or policies in each country. Several factors can explain this result, including the fact that although ET requires significant EF for renewable energy infrastructure development, the energy policy changes in Indonesia, Malaysia, and Thailand may not yet be sufficient to drive EF in large amounts. EF often requires stronger incentives or policy support, which may still be limited in these countries. Furthermore, despite efforts to increase the use of renewable energy, these countries still rely on conventional energy sources such as coal and gas, which can slow down ET and affect the flow of EF to the more environmentally friendly sector. On the other hand, the unidirectional relationship could indicate that ET is more influenced by energy policies and national targets, which more frequently drive changes in EF. These countries may have policies that encourage investment in renewable energy or reduce dependence on fossil fuels, leading to higher EF in the sector. However, the existing EF may not be sufficient to drive structural changes in ET itself, which may explain why no bidirectional causality was found between the two variables. Previous studies, such as those by Long et al. (2023) and Zhou et al. (2021), found similar patterns where ET policies often trigger an increase in EF in developing countries. Additionally, Qadir et al. (2021) showed that ET initiated by CE reduction policies can promote an increase in EF in developing countries. Thus, this study highlights the important role of ET as a key driver in EF policies, particularly among ASEAN UMIC, to ensure a sustainable transition and global environmental commitment.

Third, the absence of bidirectional causality between ET and CE in ASEAN UMIC—Indonesia, Malaysia, and Thailand—can be justified by analyzing the dynamics of both variables. Although no reciprocal causal relationship was found, the study indicates a unidirectional relationship, where ET influences CE, with a probability value of 0.0156, which is below the 5% significance level. In terms of policy, these results suggest that ET policies, such as reducing dependence on fossil fuels and increasing the use of renewable energy, have the potential to lower CE. The absence of bidirectional causality between ET and CE may be due to structural factors present in these countries. While ET has the potential to reduce CE, the reduction in CE may not be entirely influenced by changes in the energy sector alone. The ASEAN countries in this study still have significant dependence on fossil fuels, which may limit the direct impact of ET policies on reducing CE. Moreover, the ET occurring in these countries may be gradual and not yet strong enough to directly alter CE trends in the short term. Limited financing for clean energy technologies, infrastructure constraints, and dependence on conventional energy sectors remain major challenges. However, despite the lack of bidirectional causality, the significant influence of ET on reducing CE suggests that policies encouraging renewable energy use and energy efficiency could be an effective step in lowering CE. The reduction in CE associated with ET indicates significant potential for these countries to contribute to achieving global climate change goals, although more aggressive policies and broader implementation will be needed to accelerate this transition. Previous research, such as that by Nam and Jin (2021), also suggests that ET can play a role in reducing CE in the long term, especially when countries begin to more widely adopt clean energy technologies. For example, research by Dong et al. (2022) identified that developing countries implementing ET policies based on renewable energy tend to experience a reduction in CE, although the effects may not be immediately visible in the short term. This underscores the importance of ET policies as a key step to reduce CE in developing countries like Indonesia, Malaysia, and Thailand, which are committed to achieving long-term sustainability and emission reduction goals.

Figure 3: IRF graph

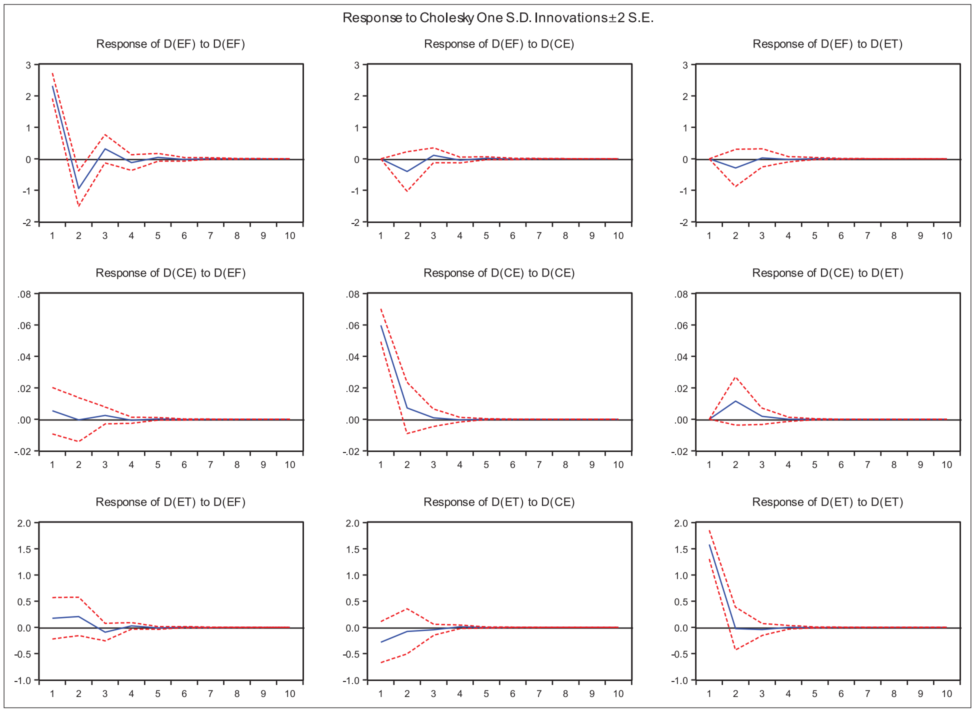


Table 8: Results of VD test

Period	S.E.	D (EF)	D (CE)	D (ET)
		VD of D (EF)		
Period	**S.E.**	**D (EF)**	**D (CE)**	**D (ET)**
1	2.321087	100.0000	0.000000	0.000000
2	2.555020	96.23057	2.468418	1.301016
3	2.577480	96.10105	2.610031	1.288917
4	2.580739	96.08219	2.628020	1.289785
5	2.581195	96.07925	2.630796	1.289956
6	2.581257	96.07886	2.631168	1.289970
7	2.581266	96.07881	2.631219	1.289972
8	2.581267	96.07880	2.631226	1.289973
9	2.581267	96.07880	2.631227	1.289973
10	2.581267	96.07880	2.631227	1.289973
		VD of D (CE)		
Period	**S.E.**	**D (EF)**	**D (CE)**	**D (ET)**
1	0.060047	0.813304	99.18670	0.000000
2	0.061572	0.775885	95.69082	3.533299
3	0.061657	0.930994	95.44969	3.619314
4	0.061661	0.940996	95.44010	3.618909
5	0.061661	0.942437	95.43871	3.618857
6	0.061662	0.942653	95.43849	3.618855
7	0.061662	0.942682	95.43846	3.618854
8	0.061662	0.942686	95.43846	3.618854
9	0.061662	0.942686	95.43846	3.618854
10	0.061662	0.942686	95.43846	3.618854
		VD of D (ET)		
Period	**S.E.**	**D (EF)**	**D (CE)**	**D (ET)**
1	1.613436	1.145356	3.046654	95.80799
2	1.628564	2.731226	3.209777	94.05900
3	1.632301	3.029535	3.274228	93.69624
4	1.632570	3.057836	3.276708	93.66546
5	1.632611	3.062203	3.277006	93.66079
6	1.632617	3.062809	3.277059	93.66013
7	1.632618	3.062891	3.277066	93.66004
8	1.632618	3.062903	3.277067	93.66003
9	1.632618	3.062904	3.277067	93.66003
10	1.632618	3.062905	3.277067	93.66003

4.7. IRF Test Results

The IRF) is an important step in VAR analysis used to measure the response of variables to shocks in other variables within the model. The IRF test helps in understanding the dynamic patterns of relationships between variables, particularly in how they respond to temporary disturbances and how quickly or slowly the effects of these shocks dissipate. In the context of a VAR model, the IRF results can show how specific variables react over time to an initial shock, providing insights into the stability and interdependence of the variables, as shown in Figure 3.

The IRF results show that the variables D(EF), D(CE), and D(ET) tend to respond strongly to shocks in their own variables at the beginning, but the effects quickly fade in the subsequent periods. D(EF) shows a significant positive response in the first period to its own shock (2.321087), which then decreases to nearly zero by the tenth period. The impact of D(CE) and D(ET) on D(EF) is small and negative from the second period onward, and it diminishes quickly, approaching zero, indicating a weak and short-lived effect. Next, D(CE) shows a significant positive response to its own shock in the first period (0.059802), which also decreases rapidly. The response of D(CE) to shocks in D(EF) and D(ET) is very small and fluctuates, but it tends to approach zero over time. Finally, D(ET) shows a strong response to its own shock in the first period (1.579256), which gradually decreases in the following periods. Overall, each variable shows high sensitivity to shocks in itself during the initial period, but the inter-variable effects tend to be weak and insignificant in the long term.

4.8. Results of VD Test

The VD test in Table 8 is an important step in VAR analysis because it informs how the variance of a variable can be explained by other variables in the model over time. The VD results for D(EF), D(CE), and D(ET) in the VAR analysis show how the variations in each variable can be explained by shocks originating from other variables in the model.

The VD results for D(EF), D(CE), and D(ET) reveal that the variation in each variable is predominantly explained by its own shocks, with minor contributions from other variables. For EF, nearly all of its variation is accounted for by D(EF) itself, approximately 96.07% in the 10th period, with small contributions from D(CE) and D(ET), at around 2.63% and 1.29%, respectively, in the same period. Similarly, CE in the first period is almost entirely explained by D(CE), around 95.43% in the 10th period, with minimal contributions from D(EF) at 0.94% and D(ET) at 3.61%. Although the influence of D(EF) slightly increases over time, it remains relatively small. Meanwhile, D(ET) is largely explained by its own shocks, around 93.66% in the 10th period, with smaller contributions from D(EF) and D(CE) at approximately 3.06% and 3.62%, respectively. These findings indicate that while there are minor inter-variable influences, each variable is predominantly driven by its internal factors. EF and ET tend to be influenced more by energy-related internal dynamics, whereas CE is primarily shaped by its own internal factors in the short term.

5. CONCLUSION

This study highlights the complex relationship between EF, CE, and ET in Indonesia, Malaysia, and Thailand, classified as UMICs in ASEAN. Using a VAR approach with data from 2000 to 2023, the study found no direct causal relationship among the three variables. However, the results indicate a significant unidirectional influence, where CE and ET significantly affect EF, while ET also significantly influences CE. This finding provides valuable insights into the complex dynamics between EF, ET, and CE. Although these three variables interact with each other, a clear causal relationship between them cannot be identified, suggesting the presence of external factors or other interventions that influence this relationship. This indicates that while EF, which plays a crucial role in supporting ET, is not entirely driven by CE, there is a significant potential for the demand for EF to increase as CE rises and ET efforts intensify. In other words, when EF, particularly dominated by fossil energy sources, increases significantly and is followed by a rise in CE, these countries tend to respond by allocating more funds to the energy sector, either to accelerate ET or to maintain energy supply stability. However, although these fund allocations aim to support ET, the increased dependence on fossil energy in these efforts may worsen the negative environmental impacts, increase the carbon footprint, and hinder the achievement of long-term sustainability goals. In this context, these dynamics highlight the need for a more holistic and integrated approach to planning and managing EF to ensure truly sustainable ET, both economically and environmentally.

The policy implications of these findings are far-reaching, particularly when it comes to achieving a more sustainable ET. One of the primary recommendations is the urgent need to enhance incentives for investments in renewable energy, which could significantly reduce reliance on fossil fuel-based energy while simultaneously lowering CE. Governments in these three countries should prioritize increasing EF for clean energy projects, such as solar and wind power plants, which are key to reducing dependence on coal and oil. In this regard, although there is a clear interplay between ET and EF, transitioning to clean energy is an essential step in securing long-term economic growth and environmental sustainability. Moreover, these findings highlight that effective energy policies aimed at reducing CE require more than just technological advancements; they also necessitate a fundamental shift in the structure of EF itself. For ASEAN countries, including Indonesia, Malaysia, and Thailand, it is crucial to design and implement policies that not only accelerate renewable energy investments but also foster the development of green infrastructure. Such policies should ensure that EF is strategically directed toward supporting environmentally friendly ET. With the right set of policies, these nations can make significant progress toward achieving a more sustainable ET, which would ultimately contribute to a reduction in CE and help mitigate the adverse impacts of climate change. Through these concerted efforts, they can transition toward a cleaner, more sustainable energy future that benefits both the economy and the environment.

Nonetheless, this study has certain limitations, particularly concerning its methodological approach. The use of the VAR model, while effective for analyzing short-term relationships among variables, may not fully capture the deeper, dynamic interactions between EF, CE, and ET over the long term. Additionally, the study does not account for potential external variables or macroeconomic factors, such as government policies or global energy price fluctuations, which could influence these relationships. As a result, although the findings suggest no clear causal relationship, a more comprehensive approach and the use of more specific models may be needed to better understand the complex dynamics underlying these phenomena.

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