

Is There Causality Relationship between Corporate Performance and Energy Efficiency? An Empirical Evidence from Fertilizer Industry in Indonesia

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Abstract

This study examines the dynamic relationship between corporate performance, energy efficiency, and environmental & social responsibility cost (ESRC) using panel data from six fertilizer companies in Indonesia over the period 2013–2024. The analysis employs the Panel Vector Autoregression (PVAR) model and Granger causality test to capture interdependencies and causal linkages among variables. The results reveal that corporate performance, energy efficiency, and ESRC exhibit strong dynamic persistence and interact in a complex manner across time. Energy efficiency is found to significantly influence corporate performance, while ESRC also plays a crucial role in shaping firm performance. Furthermore, a bidirectional causal relationship exists between energy efficiency and ESRC, indicating their complementary roles in supporting sustainable business practices. These findings suggest that sustainability-related investments may impose short-term costs but generate long-term benefits through improved efficiency and competitiveness. The study highlights the importance of integrating energy efficiency and social-environmental responsibility into corporate strategy. It provides empirical evidence that sustainability practices are key drivers of long-term firm performance, particularly in energy-intensive industries such as fertilizer production.

Keywords: corporate performance, energy efficiency, environmental and social responsibility cost (ESRC)

1. Introduction

Changes of the global business landscape over the past decade have shown that sustainability issues have become a key determinant of company performance, particularly in energy-intensive industrial sectors. Pressure on companies to improve energy efficiency and strengthen socio-environmental responsibility is increasing in line with global commitments to the energy transition and carbon emission reduction. A 2023 report from the International Energy Agency states that global investment in energy efficiency has increased by approximately 45% since 2020, reflecting the strategic role of energy efficiency in enhancing economic competitiveness and sustainability. However, the impact of these investments is not immediate; it takes time to produce significant results on company performance.

In this context, the relationship between energy efficiency and corporate performance becomes increasingly relevant to study. Energy efficiency is not only related to reducing energy

consumption but also reflects a company's ability to manage resources optimally. Empirical studies show that companies with high levels of energy efficiency tend to have more efficient cost structures and lower operational risks. For example, studies by Shahbaz et al. (2020) and Zhang et al. (2022) found that energy efficiency positively contributes to company profitability, particularly in industrial sectors with high energy intensity. However, some studies also indicate negative short-term effects due to the high initial investment costs in energy-efficient technologies.

In addition to energy efficiency, environmental and social responsibility costs (ESRC) are also a significant factor influencing company performance. From a modern perspective, these expenses are no longer considered a burden but as a strategic investment to enhance a company's reputation and legitimacy. A study conducted by Nguyen et al. (2020) pointed out that CSR spending can reduce profitability in the short term and provides long-term benefits through increased customer loyalty and market access. This finding is consistent with empirical research by Fatemi et al. (2021), who found that ESG performance has significant value relevance to increasing company value. Furthermore, the link between energy efficiency and ESG indicates a complementary relationship. Investments in energy efficiency are often part of a company's environmental responsibility strategy, making the two variables inseparable in modern business practices. Research by Aouadi and Marsat (2021) shows that companies with a strong commitment to ESG practices tend to have better operational efficiency and lower risk levels. Furthermore, recent studies found that companies with strong ESG performance are better able to withstand conditions of energy uncertainty and maintain their financial performance (Wang et al., 2025).

However, empirical research on the relationship between these three variables remains inconsistent. Some studies pointed out a positive relationship between ESG and corporate performance, while others found no significant effect. For example, research on energy companies in Indonesia and Malaysia found that ESG disclosure had no significant effect on short-term financial performance (Sari & Putra, 2023). These discrepancies reflect that the relationship between corporate performance, energy efficiency, and ESG disclosure depends on industry characteristics, cost structure, and the time horizon of the analysis.

In the Indonesian context, particularly in the fertilizer industry, studies on the dynamic relationship between these three variables are relatively limited. The fertilizer industry is a highly energy-intensive sector with significant environmental impacts, making energy efficiency and socio-environmental responsibility key factors in determining business sustainability. However, most previous studies have focused on the manufacturing sector in general or used a static approach, thus failing to capture the dynamic relationships between these variables.

Based on these gaps, this study aims to analyze the dynamic relationship between corporate performance, energy efficiency, and environmental & social responsibility costs using a panel data approach in six fertilizer companies in Indonesia during the period 2013–2024. By integrating dynamic analysis and causality testing, this study provides empirical contributions

to understanding how sustainability strategies affect company performance in the short and long term, as well as provides relevant policy implications for the development of a sustainable fertilizer industry.

2. Literature Review

Recent literature confirms that the link between corporate performance, energy efficiency, and environmental and social responsibility costs (ESRC) is a crucial component of a sustainable business strategy. In the modern context, companies are no longer solely focused on achieving short-term profits but also on creating long-term value through the integration of environmental and social aspects. Numerous researchers have studied the relationship between energy efficiency, environmental and social responsibility costs (ESRC), and corporate performance. For instance, several empirical studies have demonstrated a positive correlation between energy efficiency and corporate performance (Cagno et al., 2022). Improved energy efficiency contributes significantly to corporate profitability, primarily through reduced energy costs (Bergmann et al., 2017). Zhang et al. (2022) demonstrated in their research that energy-saving policies have a positive impact on corporate financial performance. Consistent with the aforementioned research, an empirical study by Taghavi (2022) concluded that implementing energy efficiency measures not only increases operational efficiency but also improves overall production performance.

In contrast to the researchers mentioned above, several studies have shown more complex and inconsistent results. Ahmad et al. (2024) found that the effect of resource efficiency on financial performance is highly dependent on production costs as a moderating variable. Previously, Naeem et al. (2022) demonstrated that the relationship between environmental performance (including energy efficiency) and financial performance varies between developed and developing countries, highlighting the influence of institutional and market contexts.

Empirical research on the relationship between environmental and social costs and corporate performance has not yet reached a consistent conclusion. However, most of the literature indicates a positive relationship between the two variables. Becchetti et al. (2008) and Rodríguez-Fernández (2016) found that CSR investments can improve financial performance through improved reputation and governance. Coelho et al. (2023) also confirmed that strategic CSR integration contributes to increased profitability. Other studies, such as Sharma and Chakraborty (2024) and Dela et al. (2024), suggest that the economic benefits of social and environmental costs could arise through improved competitiveness and market position. However, studies on the relationship between the two variables also show mixed and inconsistent results. Najihah et al. (2021) show that CSR costs do not always have a significant impact on financial performance, especially in the short term. Aqabna et al. (2023) revealed that during a crisis, this relationship depends on earnings management practices. Furthermore, Khalil et al. (2026) & Narzari et al. (2026) emphasized that the strength of the relationship is highly dependent on the company context and business environment.

Furthermore, the study of the relationship between energy efficiency and environmental

corporate responsibility costs has become a significant focus in the sustainability and corporate performance literature. Sahoo et al. (2022) found that companies with strong CSR practices tend to have higher levels of energy efficiency, suggesting a reciprocal relationship between environmental investment and operational efficiency. Tylżanowski et al. (2023) also showed that energy efficiency is an integral part of the environmental dimension of CSR, suggesting that companies that improve energy efficiency tend to increase spending on environmental activities. Liu et al. (2024) and Safi et al. (2023) added that social and environmental responsibility drives environmental investment through information transmission and resource acquisition mechanisms, ultimately improving energy efficiency. Furthermore, Wang et al. (2025) and Yang et al. (2025) demonstrated that ESG performance and corporate green initiatives contribute to improved energy efficiency and strengthened sustainability strategies. Thus, energy efficiency and environmental responsibility costs have a mutually reinforcing relationship within the framework of sustainable development.

Several other empirical studies demonstrate that the relationship between energy efficiency and environmental responsibility costs is not always linear and can be complex. Ali et al. (2025) found that corporate environmental responsibility does not always directly improve environmental performance without an effective strategy. Wang & Li (2024) emphasized that the effect of environmental responsibility on sustainability performance is highly dependent on the mediating role of a company's environmental strategy. Furthermore, Madwe et al. (2025) found that although energy efficiency has a positive impact on financial performance, its implications for environmental responsibility costs can vary depending on industry characteristics and regulatory pressures.

3. Research Method

The methodology must this study uses secondary data sourced from Key Performance Indicator Reports and Sustainability Reports. The data is in the form of panel data from six fertilizer companies in Indonesia for the period 2013-2024. These companies consist of PT Pupuk Indonesia (Persero), PT Pupuk Kalimantan Timur, PT Petrokimia Gresik, PT Sriwidjaja Palembang, PT Pupuk Iskandar Muda, and PT Pupuk Kujang Cikampek.

The operationalized variables in this study are composed of corporate performance, energy efficiency, and environmental and social responsibility costs. Corporate performance is proxied by the score of key performance indicators (KPIs). The use of KPIs as a measure of corporate performance is emphasized by several researchers (Elzahar et al., 2015; Silva & Borsato, 2017; Munmun et al., 2023). Furthermore, energy efficiency is expressed as the ratio of energy output required to produce output (Caragliu, 2021; Jan et al., 2023). In this study, energy efficiency focuses on energy efficiency for Urea fertilizer products, measured in mmbtu/ton. Finally, environmental and social responsibility costs refer to the growth in costs incurred by the company expressed as a percentage.

A first stage in my empirical study is represented by the analysis of stationary. I used the Levine–Lin–Chu (LLC) method (Levine, Lin, & Chu, 2002) and the Im–Pesaran–Shin (IPS) method (Im, Pesaran, & Shin, 2003) to check the order of integration to see where the time series

variable attains stationary. Both the LLC and IPS methods were deployed on the principles of the conventional Augmented Dickey–Fuller (ADF) test. The LLC method explores the heterogeneity of intercepts across members of the panel, while the IPS method explores the heterogeneity in the intercepts, as well as in the slope coefficients. Both tests were applied by averaging individual ADF t-statistics across cross-section units.

The second stage in the method of the analysis is co-integration test. The concept of co-integration, introduced by Granger (1969), is relevant to the problem of determining long-run relationship between the variables. The basic idea that underpins co-integration is simple. If the difference between two non-stationary series is itself stationary, then the two series are co-integrated. If two or more series co-integrated, it is possible to interpret the variables in these series as being in a long-run equilibrium relationship (Engle & Granger, 1987). By contrast, a lack of co-integration suggests that the variables have no long-run relationship-thus, in principle, the postulated variables can arbitrarily move far away from each other.

In the three stage, the causality analysis between the three variables is performed by means of a panel vector auto regression (PVAR) model. The panel data VAR methodology combines the traditional VAR approach, which treats all the variables in the system as endogenous, with the panel-data approach, which allows for unobserved individual heterogeneity (Grossmann et al., 2014). The optimal of lag length is evaluated by means of the Schwarz information criterion. VAR model employed to examine the causality relationship among corporate performance, energy efficiency and environmental & social responsibility cost formulated as follow:

$$\log CP_{it} = \alpha_0 + \sum_{j=1}^n \beta_{1j} \log CP_{i,t-j} + \sum_{j=1}^n \beta_{2j} \log EE_{i,t-j} + \sum_{j=1}^n \beta_{3j} ESSC_{i,t-j} + \mu_{it}$$

$$\log EE_{it} = \alpha_0 + \sum_{j=1}^n \beta_{1j} \log CP_{i,t-j} + \sum_{j=1}^n \beta_{2j} \log EE_{i,t-j} + \sum_{j=1}^n \beta_{3j} ESSC_{i,t-j} + \varepsilon_{it}$$

$$ESSC_{it} = \alpha_0 + \sum_{j=1}^n \beta_{1j} \log CP_{i,t-j} + \sum_{j=1}^n \beta_{2j} \log EE_{i,t-j} + \sum_{j=1}^n \beta_{3j} ESSC_{i,t-j} + v_{it}$$

Where $\log CP$ denotes the natural logarithm of key performance indicator score as proxies of corporate performance, $\log EE$ denotes the natural logarithm of realization of energy usage for urea as proxies of energy efficiency, and $ESSC$ denotes the growth of environmental & social responsibility cost, i denotes the corporate of i , and t denotes the period of t . Furthermore, α and β are constants to be estimated, as well as μ , ε and v denotes a stochastic error term of the PVAR equation, respectively.

In the next stage, we test the causality relationship between the three variables using Granger Causality VAR methods, so that we can clearly know whether energy efficiency (EE) has an impact on corporate performance and environmental & social responsibility cost or vice versa

the two variables cause energy efficiency. For each of the two questions, a Chi-square (Wald) test is utilized to test the significance of the effect of the respective exogenous variable statistically. Moreover, the VAR methodology allows us to analysis the impulse response that detects the manner in which each endogenous variable responds to the shocks of the exogenous variable evaluated through the residual variables. Thus, shock spread from one of certain variables to the other within the dynamic structure of the VAR model.

4. Finding and Discussion

An overview of the characteristics of the data is presented through descriptive statistical analysis and a correlation matrix of the variables used, namely corporate performance, energy efficiency, and social and environmental responsibility costs. As previously explained, this study uses panel data covering six fertilizer companies in Indonesia during the period 2013–2024, thus allowing for a more comprehensive analysis both across companies and over time. Descriptive statistics provide information on the average, median, maximum, minimum, and number of observations for each variable, thus indicating the distribution pattern and level of variation in the data. Meanwhile, a correlation matrix is used to observe the strength and direction of the linear relationship between variables, which serves as an initial basis for understanding the interrelationships between variables before further empirical analysis is conducted.

Based on Table 1, descriptive statistics show that corporate performance, as measured by KPI score, has an average of 97.92, with a median of 99.80. The maximum value reached 107.06, and a minimum of 75.17, indicating relatively stable company performance with minimal variation. The 72 observations also indicate that the data used is representative enough for further analysis. For the energy efficiency variable, measured by energy use for urea fertilizer production (mmbtu/ton), the average value was 30.04, with a median of 29.08. The maximum value of 57.52 and the minimum value of 22.26 indicate variation in energy efficiency between periods or units of analysis, generally within a controllable range. This thing reflects opportunities for energy efficiency improvement across several observations.

Meanwhile, the social and environmental responsibility costs variable, measured by cost growth, showed an average of 77.61 percent, with a median of only 8.84 percent. The significant difference between the mean and median indicates an asymmetrical (skewed) distribution of the data, likely influenced by the very high maximum value of 1803.62 percent and the minimum value of -94.47 percent. This indicates that cost growth is highly volatile and tends to be unstable.

Table 1. Descriptive Statistics And Correlation Matrix

	Corporate Performance (KPI Score)	Energy Efficiency (mmbtu/ton)	Growth of Environmental & Social Responsibility Cost (Percent)
Descriptive Statistics			
Mean	97.91778	30.04292	77.61342
Median	99.80000	29.08000	8.836401
Maximum	107.0600	57.52000	1803.617
Minimum	75.17000	22.26000	-94.47124
Observations	72	72	72
Correlation Matrix			
Corporate Performance	1		
Energy Efficiency	0.586	1	
Environmental & Social Responsibility Cost	-0.048	0.045	1

Source: Author's Computation using E-views 9.0.

Furthermore, the correlation matrix results show a fairly strong positive relationship between corporate performance and energy efficiency, with a correlation coefficient of 0.586. This coefficient indicates that increased energy efficiency tends to be followed by increased corporate performance, or vice versa. However, this relationship requires further analysis in an empirical model to confirm the direction of causality. On the other hand, the relationship between corporate performance and social and environmental responsibility costs shows a very weak correlation of -0.048. This coefficient indicates that changes in social and environmental responsibility costs are not directly related to changes in corporate performance. Similarly, the correlation between energy efficiency and social and environmental responsibility costs is also very weak, at 0.045, indicating that the two variables have a relatively insignificant linear relationship.

The initial stage in dynamic panel data analysis is testing the data for stationarity using the panel unit root test. This test is crucial to ensure that the variables used do not contain unit roots, thus avoiding spurious regression. In this study, stationarity testing was conducted on three main variables: corporate performance, energy efficiency, and the growth of environmental and social responsibility, using four approaches: Levin, Lin & Chu (LLC), Im, Pesaran & Shin (IPS), ADF-Fisher Chi-square, and PP-Fisher. The test results are in Table 2.

Table 2. The Result Of Panel Unit Root Test

No	Variable	Methods	Include in Test Equation:			
			Individual Intercept		Individual Intercept & Trend	
			t-stat	p-value	t-stat	p-value
1	Corporate Performance	Levin, Lin & Chu	-0.49236	0.3112	-2.18157	0.0146
		Im, Pesaran & Shin	-0.24750	0.4023	-1.83988	0.0329
		ADF - Fisher X ²	11.3089	0.5026	22.1601	0.0358
		PP – Fisher	32.2123	0.0013	63.4634	0.0000
2	Energy Efficiency	Levin, Lin & Chu	0.10982	0.5437	1.05708	0.8548
		Im, Pesaran & Shin	-1.78580	0.0371	-1.54019	0.0618
		ADF - Fisher X ²	21.2121	0.0474	21.9105	0.0385
		PP – Fisher	55.8403	0.0000	69.9767	0.0000
3	Environmental & Social Responsibility Cost	Levin, Lin & Chu	-1.27529	0.1011	0.33138	0.6298
		Im, Pesaran & Shin	-1.91512	0.0277	-0.49799	0.3092
		ADF - Fisher X ²	21.4415	0.0443	14.6331	0.2621
		PP – Fisher	57.6923	0.0000	55.7918	0.0000

Source: Author's Computation using E-views 9.0

As in table 2 above, based on the test results at the level with the assumption of individual intercept, the corporate performance variable is not fully stationary, as indicated by the probability values in the LLC method (0.3112), IPS (0.4023), and ADF-Fisher (0.5026) which exceed the 5% significance level, while only PP-Fisher is significant at the 1% level (0.0013); however, when the individual intercept and trend are included, all methods indicate stationarity. For the energy efficiency variable, most methods on the individual intercept have indicated stationarity, especially IPS (0.0371), ADF-Fisher (0.0474), and PP-Fisher (0.0000), although LLC is not significant, and these results are relatively consistent in the specification with a trend, although IPS is at the limit of significance (0.0618). Meanwhile, the environmental & social responsibility cost growth variable shows stronger results on the individual intercept, where IPS (0.0277), ADF-Fisher (0.0443), and PP-Fisher (0.0000) are significant, but when the trend is entered, only PP-Fisher remains significant, thus indicating that the test results for this variable tend to be sensitive to model specifications.

Based on the explanation above, the overall results of the panel unit root test indicate that most variables have met the stationarity assumption at the level, especially when considering the trend in the model. Thus, it concluded that the data used in this study are generally stationary, making them suitable for further analysis using the Panel VAR model. However, differences in results between methods still need to be observed as a form of caution in interpreting subsequent estimation results.

To test the existence of a long-run relationship between variables in a panel data framework, this study applies the residual-based cointegration test developed by Pedroni. This approach is important because it allows testing whether corporate performance, energy efficiency, and

environmental & social responsibility costs move together in a long-run equilibrium, even though each variable is individually non-stationary. The Pedroni test provides several test statistics grouped into within (panel) and between (group means) dimensions, and considers model specifications with individual intercepts and individual intercepts and trends, thus providing a more comprehensive evaluation of the possibility of cointegration in panel data. The test results are presented in Table 3.

Table 3. The Result Of Pedroni's Residual-Based Cointegration Test

Panel Cointegration Statistics (Within-Dimension)		
Test Statistics	Statistical Values	
	Individual Intercept	Individual Intercept and Trend
Panel v-Statistic	-1.240167 (0.8925)	-2.348833 (0.9906)
Panel rho-Statistic	-0.680605 (0.2481)	0.116978 (0.5466)
Panel PP-Statistic	-3.605157 (0.0002)	-7.322811 (0.0000)
Panel ADF-Statistic	1.145741 (0.8740)	-0.790508 (0.2146)
Group Mean Panel Cointegration Statistics (Between-Dimension)		
Test Statistics	Statistical Values	
	Individual Intercept	Individual Intercept and Trend
Group rho-Statistic	0.475136 (0.6827)	1.251416 (0.8946)
Group PP-Statistic	-3.340925 (0.0004)	-14.94993 (0.0000)
Group ADF-Statistic	1.568069 (0.9416)	-1.348681 (0.0887)

Source: Author's Computation using E-views 9.0

Table 4. The Result of Kao's Residual Panel Cointegration Test

Null Hypothesis: No cointegration	T-Statistic	P-value
ADF	1.243285	0.1069
Residual Variance	0.006192	
HAC Variance	0.001598	

Source: Authors' Computation using E-views 9.0

The Pedroni cointegration test results show limited indications of a long-term relationship between variables, but they are not fully consistent across all test statistics. In the within-dimension approach, only the Panel PP statistic is significant under both the individual intercept (p-value 0.0002) and the individual intercept and trend (p-value 0.0000), while other statistics,

such as Panel v, rho, and ADF, are insignificant. Similar results are also seen in the between-dimension approach, where only the Group PP statistic is significant in both specifications, while Group rho and Group ADF are generally insignificant, although Group ADF approaches significance at the 10% level in the model with a trend (p-value 0.0887). Meanwhile, the Kao cointegration test shows a p-value of 0.1069, which is insignificant at the 5% level, thus disproving the existence of cointegration. Thus, overall, the evidence for cointegration between variables remains weak and inconsistent, and therefore, a strong conclusion cannot be drawn that a long-run equilibrium relationship exists. Since there is no strong evidence of cointegration between the variables, as indicated by the inconsistent results of the Pedroni test and the insignificant Kao test (p-value 0.1069), the use of a Panel VAR model in the form of a level (unrestricted Panel VAR) is more recommended. This approach is appropriate because the Panel VAR model does not require a long-run equilibrium relationship (cointegration), so it can still be used to analyze the dynamics of short-run relationships between variables simultaneously.

Before estimating a VAR model to analyze the dynamic relationship between corporate performance, energy efficiency, and environmental and social responsibility costs, the important step is to determine the optimal lag length. Selecting the right lag is necessary to adequately capture the dynamics of adjustments between variables while avoiding overfitting and inefficient model specifications. Therefore, this study uses several lag selection criteria commonly used in VAR analysis, namely the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan–Quinn Criterion (HQ). The results of the comparison of these five criteria in determining the optimal lag are presented in Table 4.

Table 5. The Result Of VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-215.2388	NA	6.545126	10.39232	10.51644	10.43782
1	-172.1783	77.91904	1.294988	8.770395	9.266872	8.952374
2	-161.2728	18.17583	1.191774	8.679657	9.548492	8.998120
3	-130.2602	47.25729	0.425606	7.631438	8.872631*	8.086384
4	-118.8295	15.78520	0.392598	7.515693	9.129243	8.107123
5	-102.1691	20.62726*	0.288980*	7.150908*	9.136816	7.878822*

Source: Author's Computation using E-views 9.0

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Based on the results of the VAR Lag Order Selection Criteria in Table 4, most of the information criteria indicate that the optimal lag for the VAR model is at lag 5. This can be seen from the

asterisk (*) that marks the best value on several main criteria, namely Likelihood Ratio (LR), Final Prediction Error (FPE), Schwarz Criterion (SC), and Hannan–Quinn Criterion (HQ), all of which minimize prediction error or model complexity at lag 5..

After determining the optimal lag length and testing the dynamic nature of the relationship between variables, the next stage in this study is to estimate a panel vector autoregressive (Panel VAR) model to analyze the reciprocal relationship between corporate performance, energy efficiency, and environmental & social responsibility costs simultaneously. The application of the Panel VAR approach is due to its ability to allow all variables to be treated as endogenous, allowing the dynamics of adjustment to be traced through the influence of each variable's past value on the other variables within the panel data framework. By using the established lag structure, the results of coefficient estimates, statistical test values, and model fit measures are summarized in Table 5.

Tabel 6. The Summary Of Panel Vector Autoregressive

Exogenous Variable	Endogenous Variable					
	Corporate Performance		Energy Efficiency		Environmental & Social Responsibility Cost	
	Coefficient	t-test	Coefficient	t-test	Coefficient	t-test
logCP (-1)	-0.339931	-2.64781	0.042221	0.38260	-1758.097	-1.91610
logCP (-2)	-0.025929	-0.19812	-0.088543	-0.78706	-3283.574	-3.51039
logCP (-3)	0.367300	3.00588	-0.147126	-1.40077	1227.347	1.40539
logCP (-4)	0.021087	0.17525	0.309110	2.98865	341.6420	0.39727
logCP (-5)	-0.289067	-2.06484	0.125502	1.04295	-402.9117	-0.40270
logEE (-1)	0.257981	1.42893	0.876573	5.64853	-1931.185	-1.49668
logEE (-2)	-0.151678	-0.91091	-0.454820	-3.17775	2181.596	1.83320
logEE (-3)	0.110989	1.04406	0.701893	7.68142	-811.6604	-1.06832
logEE (-4)	-0.167960	-1.13167	-0.368505	-2.88856	-1055.141	-0.99473
logEE (-5)	0.265460	3.23640	0.166351	2.35946	914.1157	1.55935
ESRC (-1)	1.39E-05	0.63826	-1.79E-05	-0.95712	-0.144645	-0.93222
ESRC (-2)	1.03E-05	0.44422	5.76E-05	2.89523	-0.099851	-0.60410
ESRC (-3)	1.97E-05	0.94495	4.49E-05	2.50103	0.337091	2.26034
ESRC (-4)	1.31E-05	0.55482	2.95E-05	1.45576	0.050605	0.30047
ESRC (-5)	4.88E-05	1.86438	-1.13E-05	-0.50423	0.169913	0.90899
C	6.889072	5.61329	-0.854199	-0.80973	20273.60	2.31136
R-squared	0.763564		0.967842		0.597668	
Adj. R-squared	0.627159		0.949289		0.365554	
Sum sq. resids	0.037520		0.027721		1916472.	
S.E. equation	0.037988		0.032653		271.4967	
F-statistic	5.597767		52.16724		2.574887	
Log likelihood	87.83615		94.19224		-284.8903	
Akaike AIC	-3.420769		-3.723440		14.32811	

Exogenous Variable	Endogenous Variable					
	Corporate Performance		Energy Efficiency		Environmental & Social Responsibility Cost	
	Coefficient	t-test	Coefficient	t-test	Coefficient	t-test
Schwarz SC	-2.758800		-3.061471		14.99008	
Mean dependent	4.608765		3.371074		0.597668	
S.D. dependent	0.062213		0.145001		0.365554	
Determinant resid covariance (dof adj.)			0.109732			
Determinant resid covariance			0.026032			
Log likelihood			-102.1691			
Akaike information criterion			7.150908			
Schwarz criterion			9.136816			

Source: Author's Computation using E-views 9.0

The results of the Panel VAR model estimation show that the dynamics of the relationship between corporate performance, energy efficiency, and environmental and social responsibility costs can be explained through the perspectives of the resource-based view and stakeholder theory. According to the resource-based view, energy efficiency is viewed as a strategic capability that can enhance a company's competitive advantage through cost reduction and increased productivity. Meanwhile, stakeholder theory emphasizes the importance of social and environmental responsibility in maintaining corporate legitimacy. The high R-squared value in the energy efficiency equation (0.9678) indicates that the variables in the model are highly capable of explaining variations in energy efficiency, while the R-squared value in the corporate performance equation (0.7636) also indicates strong explanatory power. This thing confirms the findings of Bergmann et al. (2017) and Madwe et al. (2025) that energy efficiency is a key factor in improving a company's financial performance, particularly in energy-intensive industrial sectors such as the fertilizer industry.

In the corporate performance equation, the significance of several lags of logCP (both negative and positive) indicates a nonlinear dynamic adjustment process. Negative coefficients on logCP(-1) and logCP(-5) indicate a correction effect (mean reversion), where performance improvements in the previous period tend to be followed by downward adjustments in the following period. Conversely, a positive coefficient on logCP(-3) indicates medium-term performance momentum. This phenomenon aligns with the views of Elzahar et al. (2015) and Munmun et al. (2023) that performance indicators such as KPIs are dynamic and reflect a continuous cycle of evaluation and adjustment within an organization. Furthermore, the significant positive effect of logEE(-5) on CP suggests that energy efficiency does not provide an immediate economic impact but rather takes time to realize. This finding aligns with Zhang et al. (2022) and Caragliu (2021), pointing out that investments in energy efficiency increase profitability by reducing operational costs in the medium to long term.

In the energy efficiency equation, the dominant influence of the lag variable itself indicates a strong path dependency. Significant coefficients on logEE(-1), logEE(-2), logEE(-3), logEE(-

4), and $\log EE(-5)$, both positive and negative, reflect that changes in energy efficiency do not occur instantly, but rather through a gradual process influenced by past conditions. This pattern indicates an organizational learning curve and the cumulative effects of technology investments and managerial practices. This finding is consistent with Cagno et al. (2022), who emphasized that energy efficiency requires time and integration into operational processes, and Taghavi (2022), who showed that increasing energy efficiency is highly dependent on the consistency of operational strategies. Furthermore, the significant positive effect of $\log CP(-4)$ on EE indicates that companies with better performance have the financial and managerial capacity to invest in energy-efficient technologies. This is in line with the findings of Arias et al. (2025), who confirmed a bidirectional relationship between operational efficiency and financial performance.

Meanwhile, in the ESRC equation, the estimation results show that the influence of variables is relatively weak and inconsistent. Several coefficients from $\log CP$, particularly $\log CP(-2)$, which is significantly negative, indicate that increased company performance is not accompanied by increased spending on social and environmental responsibility. This statistical result indicates that companies are more focused on cost efficiency or have different resource allocation priorities. This finding provides a more complex perspective compared to the research results of Becchetti et al. (2008) and Coelho et al. (2023), which generally found a positive relationship between CSR and company performance. However, these results can still be explained by the specific industry context and cost pressures, as suggested by Aqabna et al. (2023), which states that under certain conditions, companies can adjust CSR spending without sacrificing financial performance.

Furthermore, the insignificant effect of energy efficiency on ESRC indicates that the relationship between energy efficiency and socio-environmental responsibility is not direct in the short term. This statistical evidence suggests that increased energy efficiency is not necessarily automatically followed by increased socio-environmental investment or costs, but may be mediated by broader corporate policies or sustainability strategies. This finding is consistent with Sahoo et al. (2022) and Tylzanowski et al. (2023), who suggest that the relationship between energy efficiency and CSR dimensions is more indirect. In fact, Adibian et al. (2025) found that energy performance has a greater influence on ESG disclosure aspects than on the magnitude of social and environmental costs themselves, suggesting a discrepancy between sustainability practices and reporting.

Referring to the explanation above, it can be stated that overall, the results of this Panel VAR confirm that the strongest and most consistent relationship occurs between corporate performance and energy efficiency, which influence each other across multiple time periods. This strengthens the argument in the literature that energy efficiency is a strategic factor that can improve competitiveness and corporate performance sustainably. In contrast, environmental and social responsibility cost variables show a more limited and unstable role in this dynamic system, indicating that their impact on corporate performance is more complex, contextual, and likely only visible in the long term. Thus, this finding makes an empirical contribution by confirming that in the context of the Indonesian fertilizer industry, energy

efficiency plays a more dominant role than social and environmental investment in influencing corporate performance, while also enriching the literature with evidence from developing countries with specific industrial characteristics.

To determine the direction of the dynamic relationship between variables in the model, the Granger causality test is important because it can identify whether a variable's past information statistically contributes to explaining and predicting the movement of another variable. In the methodological literature, Granger causality is understood not as structural causality, but rather as a time-series-based predictive relationship, where a variable is said to "Granger-cause" another variable if its past values improve the forecasting accuracy of that variable (Zhang et al., 2025). Furthermore, Troster (2018) emphasized that the Granger causality test is highly relevant in economic and financial analysis because it can reveal the direction of the transmission of influence between variables, including the possibility of one-way or two-way relationships. Therefore, before further interpretation of the relationship between Corporate performance, Energy efficiency, and environmental and social responsibility costs, this causality test is applied to assess the pattern of the dynamic relationship between the three variables. The results of the Granger causality test are presented in table 6, and the nature of causality between corporate performance, energy efficiency and environmental & social responsibility cost as seen in Figure 1.

Table 7. The Result Of Granger Causality Tests

Endogenous Variable	Exogenous Variable		
	Corporate Performance	Energy Efficiency	Environmental & Social Responsibility Cost
Corporate Performance	-	[29.659] (0.000)	[6.631] (0.249)
Energy Efficiency	[13.577] (0.019)	-	(16.793) [0.005]
Environmental & Social Responsibility Cost	[17.509] (0.004)	[20.332] (0.001)	-

Source: Author's calculation with Eviews 9.0

The Granger causality test results indicate diverse causal relationships between corporate performance (CP), energy efficiency (EE), and environmental and social responsibility cost (ESRC), reflecting the dynamics of short-term interactions within the system. In general, these findings indicate that the relationships between variables are not merely correlational but also have a specific direction of influence that can be explained theoretically. First, there is a bidirectional causal relationship between corporate performance and energy efficiency. This is evident from the significant influence of EE on CP ($\chi^2 = 29.659$; p-value = 0.000) and CP on EE ($\chi^2 = 13.577$; p-value = 0.019). These findings indicate that energy efficiency not only improves company performance, but also that good company performance enables energy efficiency improvements through technology investment and operational improvements. These

results are consistent with studies by Bergmann et al. (2017), Madwe et al. (2025), and Arias et al. (2025), which found that energy efficiency and company performance are mutually reinforcing. Furthermore, Zhang et al. (2022) also emphasized that increased energy efficiency contributes to increased profitability, while more profitable companies have a greater capacity to adopt energy-saving technologies.

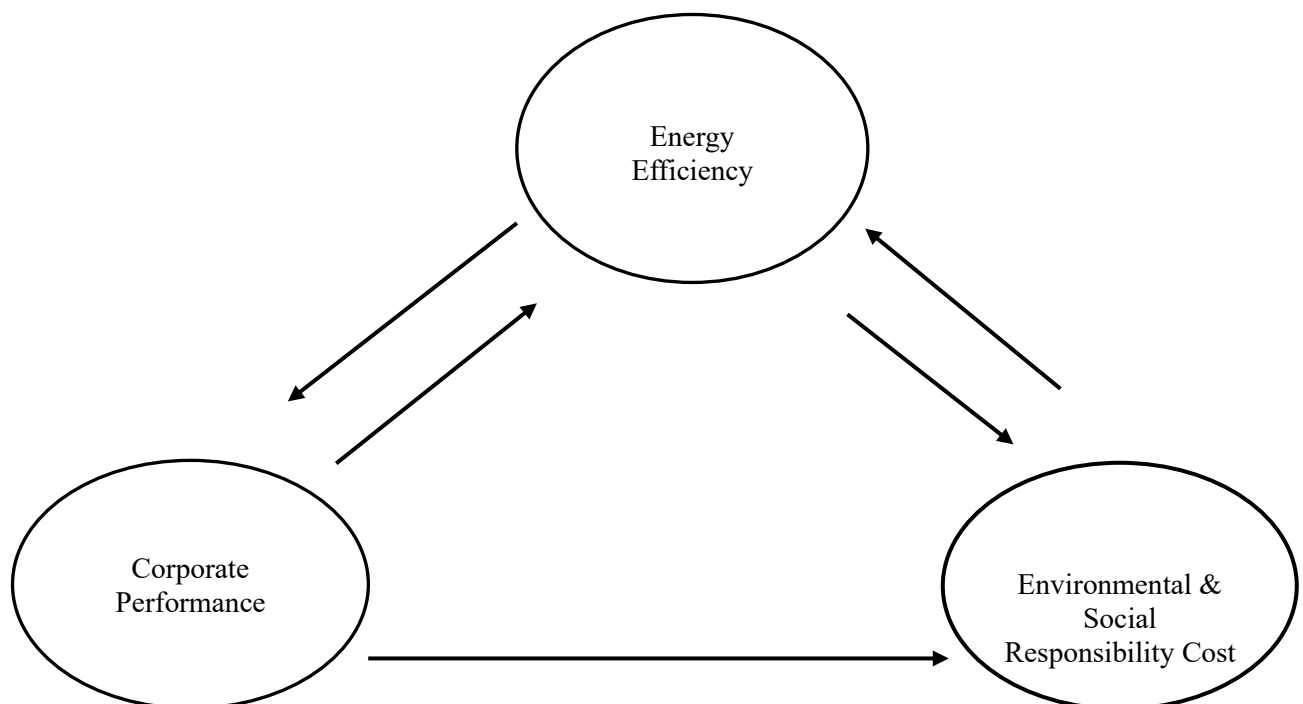


Figure 1. The Nature Of Causality Between Corporate Performance, Energy Efficiency And Environmental & Social Responsibility Cost

Second, there is no causal relationship between environmental and social responsibility costs and corporate performance ($\chi^2 = 6.631$; p-value = 0.249), indicating that in the short term, changes in environmental and social responsibility costs do not directly affect company performance. However, there is a causal relationship between CP and ESRC ($\chi^2 = 17.509$; p-value = 0.004). This indicates that better company performance encourages increased allocation of costs for social and environmental responsibility. This finding aligns with Rini & Adhariani (2021) and Safi et al. (2023), which show that companies with strong financial performance tend to have a greater capacity to increase CSR activities. Furthermore, the insignificant effect of ESRC on CP is also consistent with several studies, such as Aqabna et al. (2023), which found that the impact of CSR on performance is not always direct and often depends on the context and time period.

Based on the figure above, the causal relationship between energy efficiency *and* environmental and social responsibility cost exhibits a bidirectional pattern that is statistically significant. This

is indicated by the probability value of the effect of energy efficiency *on* environmental and social responsibility cost, which is 0.005—below the 5% significance level—thereby confirming a significant causal effect. Conversely, the effect of environmental and social responsibility cost *on* energy efficiency is also statistically significant, with a probability value of 0.001. These findings suggest that improvements in energy efficiency can drive changes in the allocation of environmental and social responsibility costs, while, at the same time, increased spending in these areas encourages firms to enhance their energy efficiency. Therefore, a strong interdependent relationship exists between the two variables in supporting corporate sustainability strategies. This finding aligns with Sahoo et al. (2022) and Tylżanowski et al. (2023), who emphasize that energy efficiency is a crucial component of the environmental dimension of CSR. Furthermore, Adibian et al. (2025) show that energy performance has a significant impact on a company's ESG aspects, although this effect is stronger on disclosure than on direct costs.

Overall, the results of this Granger causality test indicate that energy efficiency plays a central role in the system, both influencing and being influenced by corporate performance, and driving dynamics in environmental and social responsibility costs. Meanwhile, corporate performance also serves as a key driver for increasing social and environmental responsibility activities. In contrast, the ESRC did not demonstrate a causal effect on corporate performance, indicating that the economic benefits of social and environmental activities are likely long-term or indirect.

Thus, this finding reinforces the literature suggesting that energy efficiency is a strategic factor in improving corporate performance while simultaneously promoting sustainable practices. On the other hand, investments in social and environmental responsibility do not necessarily have a direct impact on short-term performance, suggesting that companies need to integrate CSR strategies more effectively to deliver sustainable added value.

5. Conclusion

This study concludes that income inequality in ASEAN is a multidimensional and systemic phenomenon influenced by the interaction of structural, social, technological, and institutional factors. The results of the Systematic Literature Review indicate that economic growth does not automatically generate equality, so a growth-based approach alone is inadequate. Key determinants of inequality include spatial inequality, human capital, financial inclusion, the digital divide, gender, and institutional quality. Spatial inequality and human capital are dominant factors, while the digital and institutional divides are increasingly important in the era of economic transformation. From a policy perspective, reducing inequality requires an integrated and cross-sectoral approach, through human capital development, inclusive digitalization, expanding financial inclusion, institutional reform, and regional redistribution. Theoretically, this study contributes by developing an integrative framework that combines economic, social, technological, and institutional dimensions.

However, this research suffers from limitations in the limited number of studies, the predominance of cross-sectoral approaches, and limited cross-country data. Therefore, further research is recommended to use a longitudinal approach and evidence-based policy evaluation.

Overall, reducing inequality in ASEAN requires a systemic approach based on integrated policies oriented towards equal access and economic opportunities to achieve inclusive and sustainable development.

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