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Macroeconomic Determinants of Coal Exports in Indonesia Amid Global Economic Volatility

Najwa Maulida* , P Eko Prasetyo
Universitas Negeri Semarang, Indonesia
Email: najwamau13@students.unnes.ac.id* , pekoprasetyo@mail.unnes.ac.id

ABSTRACT

This study analyzes the influence of international coal prices, the IDR/USD exchange rate, interest rates, and China's economic growth on the value of Indonesia's coal exports using the autoregressive distributed lag (ARDL) approach. Data from the 2010–2024 period *was* used to capture short-term and long-term dynamics relevant to the character of the energy commodity market. The estimation results show that international coal prices have a significant positive effect both in the short and long term, underscoring the role of global prices in determining the export performance of primary commodities. However, the exchange rate has a negative effect in the long term, indicating high import content during the production process; thus, rupiah depreciation increases operational costs in the mining sector. Since Indonesia's exports are highly dependent on China's energy demand as a major trading partner, China's economic growth has a significant positive effect on both time horizons. Meanwhile, interest rates did not significantly affect exports. The significant and large error correction value ensures an adjustment mechanism toward long-term equilibrium. This research provides new knowledge related to export policy and risk management for Indonesia's coal sector amid global economic volatility.

Keywords: *ARDL, Coal Exports, Macroeconomics, Global Volatility*

INTRODUCTION

One of the strategic energy commodities that plays an important role in a country's economic structure, especially Indonesia's, is coal. According to The Coal Hub's analysis report (2024), Indonesia controlled 38.3% of the global coal export market from January to August 2024, making it one of the world's largest coal exporters. When linked to sectors such as energy, industry, and transportation, coal has the potential to become one of Indonesia's largest sources of foreign exchange. Demand for Indonesian coal exports is dominated by Asian countries, including China, India, Japan, South Korea, Thailand, Malaysia, and the Philippines. These countries consistently rely on coal as a primary energy source to support industrialization and economic growth (Ambya and Hamzah, 2022). This positions Indonesia as a strategic trading partner in the global energy supply chain (Maulidia et al., 2019; Mori, 2020; Widya Yudha, 2023).

Various external factors have caused considerable volatility in the global energy market over the past decade, including geopolitical crises, international supply chain disruptions, and the COVID-19 pandemic. These factors affect the stability of global energy prices, ultimately impacting the coal market, including the Asian region as a major consumer. One key dynamic in the coal market is China's transformation into a net coal importer since 2009.

According to an analysis by Du et al. (Jie, Xu, and Guo, 2021), China has been a net coal importer since 2009; the surge in imports that year marked the country's growing dependence on international coal supplies. Thus, other countries may experience similar

dependencies. Due to this structural imbalance, Indonesia's position as a strategic coal supplier for Asia—particularly for industrial energy and power plants—can be strengthened.

Previous studies have identified factors affecting Indonesia's coal exports amid these global conditions. Susanto and Admi (2021) explained that the exchange rate and domestic production of destination countries do not negatively impact Indonesia's coal demand, contrary to international trade theory, while foreign exchange reserves and population growth in importing countries have a positive and significant effect.

A study by Ambya and Hamzah (2022) also found that international coal prices are a major determinant of exports; producers increase exports when the gap between domestic and international prices widens. Additionally, studies on the Indonesian and Australian coal markets show that rising domestic consumption tends to reduce export volumes due to prioritization of local energy needs. These findings confirm that coal exports are heavily influenced by international market dynamics and domestic demand conditions.

Various other primary commodities provide important references for export responsiveness to macroeconomic variables. Destiarni et al. (2021) showed that international prices, exchange rates, and GDP of destination countries affect Indonesia's CPO exports. Pratiwi (2021) emphasized that non-tariff barriers, competitiveness, and economic activity of partner countries are key determinants of palm oil exports.

Research by Irvansyah et al. (2020) found that relative prices, exchange rates, and per capita GDP of destination countries significantly affect Indonesia's textile exports. Vietnam's coffee exports follow a similar pattern, with exchange rates, international prices, and partner countries' GDP as main factors (Vo, Yang, and Tran, 2024). Another study by Eshetu (2024) found that Ethiopia's agricultural product exports are influenced by international prices, economic distance, and destination countries' GDP.

Based on the above, this study aims to analyze the influence of international coal prices, the Rupiah exchange rate against the United States dollar, global interest rates (Fed Fund Rate), and China's economic growth (GDP Growth China) on the value of Indonesia's coal exports from 2010 to 2024. The ARDL approach was chosen because it estimates short-term and long-term relationships simultaneously and suits time-series data with mixed integration rates, as used in prior studies on commodity exports in Indonesia and other countries.

Research by Bagas et al. (2023) shows that ARDL effectively analyzes the dynamics of Indonesia's coal exports, especially when macroeconomic variables have different integration levels. Mohamad (2022) also confirms ARDL's relevance for identifying determinants of primary commodity exports in the short and long term. Theoretically, this study contributes to the international trade literature on the macroeconomic determinants of coal exports in Indonesia amid global economic volatility. Practically, the results are expected to enhance understanding of macroeconomic factors affecting coal exports, particularly in Indonesia.

METHOD

To evaluate the variables that affect Indonesia's coal exports from 2010 to 2024, this study uses a quantitative approach using the time series method. The data used in this study includes international coal prices, the exchange rate of the Rupiah against the United States dollar, global interest rates (Fed Fund Rate), and China's economic growth (GDP Growth

China) sourced from the World Bank, International Trade Centre (ITC), Ministry of Energy and Mineral Resources, and the Federal Reserve Bank (FRED). The period of the data used is from 2010 to 2024. To estimate the influence of these variables on Indonesia's coal exports, this study adopts the export demand function as follows.

$$\ln(X)_t = \propto + \beta_1 \ln(P^{coal})_t + \beta_2 \ln(ER)_t + \beta_3 (INT)_t + \beta_4 \ln(Y^{gdp})_t + \varepsilon_t \quad 1)$$

where $\ln (X)_t$ is the logarithm of export value, $\ln (P^{coal})_t$is the price of coal, $\ln (ER)_t$is the exchange rate, $(INT)_t$is the interest rate, and $\ln (Y^{gdp})_t$is China's GDP.

The Autoregressive Distributed Lag (ARDL) model is used because it can estimate short-term and long-term relationships simultaneously, and is suitable for time-lapse data with different levels of integration, I (0) and I (1). In addition, ARDL is effectively used on data samples that are not too long, making them relevant to the range of research data. The ARDL model also allows the detection of adjustment dynamics through Error Correction Term (ECT) to identify the rate of return of variables to long-term equilibrium. The dynamic specifications of the ARDL model in the form of an Error Correction Model (ECM) formulated to capture short-term and long-term relationships at the same time are as follows.

$$\Delta \ln(X)_t = \alpha_0 + \sum \phi_i \, \Delta \ln(X)_{t-i} + \sum \delta_{ji} \, \Delta Z_{t-i} + \lambda_1 \ln(X)_{t-1} + \lambda_2 Z_{t-1} + \mu_t \quad (2)$$

Where $\Delta\lambda$ shows short-term changes and shows long-term coefficients.

The estimation stage begins with prerequisite testing, including unit root tests using Augmented Dickey-Fuller (ADF) to ensure data stationary, as well as determining optimal lag based on the Akaike Information Criterion (AIC). Furthermore, a bounds test is carried out to confirm the existence of cointegration or long-term relationships between variables. Once the prerequisites are met, the analysis is continued with the estimation of the ARDL model to obtain the short-term and long-term coefficients. The validity of the model was then tested using a series of classical assumption tests, which included a residual normality test (Jarque-Bera), an autocorrelation free test (Breusch-Godfrey), and a homoscedasticity test (Breusch-Pagan-Godfrey). Finally, parameter stability is checked using the CUSUM test to ensure the model is reliable in drawing conclusions.

RESULTS AND DISCUSSION

ARDL Model Estimation Results

Before the main model estimation was carried out, a series of prerequisite tests were carried out. The test results showed that all research variables had met the requirements for stationarity (integrated in order I(1)), there was a valid cointegration relationship based on the Bounds Test, and the model had passed the stability test (CUSUM) and the selection of optimal lag. Based on the fulfillment of these assumptions, the ARDL model estimation was carried out to analyze the influence of independent variables on coal exports.

Short-Term Estimation

Table 1. Short-Term Model Estimation Results

Dependent Variable: D(EKSPOR,2)				
Method: ARDL				
Date: 10/31/25 Time: 17:49				
Sample: 2011Q1 2024Q4				
Included observations: 56				
Dependent lags: 4 (Automatic)				
Automatic-lag linear regressors (4 max. lags): D(HARGA_BATUBARA)				
D(NILAI_TUKAR) D(SUKU_BUNGA) D(GDP)				
Deterministics: Restricted constant and no trend (Case 2)				
Model selection method: Akaike info criterion (AIC)				
Number of models evaluated: 2500				
Selected model: ARDL(1,3,2,3,2)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
COINTEQ*	-1.351803	0.123878	-10.91242	0.0000
D(HARGA_BATUBARA,2)	0.264033	0.076369	3.457335	0.0012
D(HARGA_BATUBARA(-1),2)	0.093025	0.081136	1.146532	0.2576
D(HARGA_BATUBARA(-2),2)	-0.164020	0.082517	-1.987706	0.0529
D(NILAI_TUKAR,2)	-1.090082	0.411294	-2.650370	0.0111
D(NILAI_TUKAR(-1),2)	0.672587	0.393419	1.709595	0.0942
D(SUKU_BUNGA,2)	0.035013	0.045931	0.762290	0.4499
D(SUKU_BUNGA(-1),2)	0.077184	0.050631	1.524436	0.1344
D(SUKU_BUNGA(-2),2)	0.118326	0.043237	2.736666	0.0089
D(GDP,2)	0.300871	0.068746	4.376545	0.0001
D(GDP(-1),2)	-0.031738	0.036127	-0.878504	0.3843
R-squared	0.865689	Mean dependent var		-0.001463
Adjusted R-squared	0.835842	S.D. dependent var		0.203152
S.E. of regression	0.082310	Akaike info criterion		-1.982485
Sum squared resid	0.304871	Schwarz criterion		-1.584648
Log likelihood	66.50958	Hannan-Quinn criter.		-1.828245
F-statistic	29.00424	Durbin-Watson stat		2.212730
Prob(F-statistic)	0.000000			
* p-values are incompatible with t-Bounds distribution.				

Based on Table 1, the COINTEQ* coefficient of –1.3518 is significant at the level of 1 percent, indicating a strong long-term adjustment mechanism between exports and their explanatory variables. This negative value indicates that about 135 percent of the long-term imbalances in the previous period were corrected in one current period, so the process towards long-term equilibrium is very fast.

The coal price variable showed a significant positive influence on exports, with a coefficient of 0.2640 and a p-value of 0.0012, which means that the increase in coal prices encouraged an increase in Indonesia's exports. However, the positive effect began to diminish after two periods, as shown by the coefficient of –0.1640 in the second lag with a significance level close to 5 percent (p = 0.0529). This shows that the surge in coal prices only has a strong

impact in the short term, while in the following period exports will experience adjustments due to market factors and temporary export contracts.

The exchange rate variable has a significant negative effect on exports in the current period, with a coefficient of -1.0901 and a p-value of 0.0111, which shows that exchange rate depreciation (the increase in the rupiah exchange rate against the dollar) actually suppresses exports. This condition may be caused by the dependence of the export sector on imported raw materials, so that the weakening of the exchange rate increases production costs. Nevertheless, the first lag of the exchange rate shows a positive effect (0.6726; p = 0.0942), which can be interpreted as the effect of export recovery after the exchange rate adjustment in the previous period.

Furthermore, the variable interest rate began to have a significant influence on the second lag with a coefficient of 0.1183 and a p-value of 0.0089, indicating that the change in interest rates had an impact on exports after a two-period pause. Rising interest rates in this context are likely to encourage capital movements and exchange rate stability, which indirectly supports export activity. Finally, China's GDP variable has a strong positive effect on exports with a coefficient of 0.3009 and a p-value of 0.0001, which confirms that the increase in economic activity in China increases demand for Indonesia's export commodities, especially coal.

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Long-Term Estimation

Table 2. Long-Term Model Estimation Results

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
D(HARGA_BATUBARA(-1))	0.552010	0.087680	6.295725	0.0000
D(NILAI_TUKAR(-1))	-1.684267	0.599300	-2.810393	0.0070
D(SUKU_BUNGA(-1))	0.029445	0.082256	0.357966	0.7218
D(GDP(-1))	0.445441	0.180938	2.461848	0.0172
C	0.012803	0.011005	1.163423	0.2501

Note: * Coefficients derived from the CEC regression.

The results of the long-term ARDL estimation in Table 2 show that some variables have a significant influence on Indonesia's exports, while others have no real effect. The coal price variable in the first lag has a positive coefficient of 0.5520 with a significance level of 1 percent, which indicates that the increase in coal prices will increase exports in the long run. This is in line with the role of coal as Indonesia's main export commodity, where rising global prices encourage an increase in export value and volume. The exchange rate variable in the first lag has a negative coefficient of -1.6843 with a significance level of 1 percent, which means that exchange rate depreciation (an increase in the rupiah exchange rate against the US dollar) reduces exports in the long run.

These findings indicate that the weakening of the rupiah actually increases import-based production costs and reduces the competitiveness of Indonesia's exports in the international market. Meanwhile, the interest rate variable in the first lag had a positive coefficient of 0.0294, but it was not statistically significant (p = 0.7218). This means that changes in interest rates have no real effect on exports in the long run. This can be due to the limited transmission of monetary policy towards the foreign trade sector, especially for commodities traded on long-term contracts. Finally, China's GDP variable in the first lag had a significant positive effect on exports with a coefficient of 0.4454 and a p-value of 0.0172. These results show that China's economic growth is driving increased demand for Indonesia's export products, especially coal and other raw materials.

Multicollinearity

Table 3. Multicollinearity Test Results

Variance Inflation Factors			
Date: 10/31/25 Time: 17:54			
Sample: 2010Q1 2024Q4			
Included observations: 56			
	Coefficient	**Uncentered**	**Centered**
Variable	**Variance**	**VIF**	**VIF**
D(EKSPOR(-1))	0.018912	3.083505	3.070075
D(HARGA_BATUBARA)	0.008320	1.732563	1.731499
D(HARGA_BATUBARA(-1))	0.014864	3.138978	3.133336
D(HARGA_BATUBARA(-2))	0.012990	2.752133	2.749665
D(HARGA_BATUBARA(-3))	0.009641	2.041785	2.040011
D(NILAI_TUKAR)	0.340711	2.033278	1.776703

D(NILAI_TUKAR(-1))	0.410406	2.449840	2.144397
D(NILAI_TUKAR(-2))	0.332471	1.970246	1.714352
D(SUKU_BUNGA)	0.003430	1.561600	1.548095
D(SUKU_BUNGA(-1))	0.003271	1.512773	1.503977
D(SUKU_BUNGA(-2))	0.003484	1.693388	1.687782
D(SUKU_BUNGA(-3))	0.002831	1.349407	1.347013
D(GDP)	0.018226	1.896942	1.841269
D(GDP(-1))	0.019642	2.060213	1.997062
D(GDP(-2))	0.001629	1.241868	1.237201
C	0.000226	1.657237	NA

The results of the Variance Inflation Factor (VIF) test showed that all variables in the model had a centered VIF value below the general threshold of 10, even most of them in the range of 1.2 to 3.1. This value indicates that there are no serious multicollinearity problems between independent variables in the ARDL model.

Autocorrelates

Table 4. Autocorrelation Test Results

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	0.727477	**Prob. F(2,38)**	0.4897
Obs*R-squared	2.065073	**Prob. Chi-Square(2)**	0.3561

The results of the Breusch-Godfrey Serial Correlation LM Test show that there are no autocorrelation problems in the model. Prob value. F(2.38) is 0.4897 and Prob. Chi-Square(2) of 0.3561, both greater than the significance level of 0.05. This means a null hypothesis that states no autocorrelation until the 2nd lag is accepted.

Heteroscedasticity

Table 5. Heteroscedasticity Test Results

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic	1.658363	**Prob. F(15,40)**	0.1011
Obs*R-squared	21.47229	**Prob. Chi-Square(15)**	0.1224
Scaled explained SS	11.35954	**Prob. Chi-Square(15)**	0.7267

The results of the Breusch-Pagan-Godfrey test show that the model does not experience heteroscedasticity problems. Prob value. F (15.40) is 0.1011, Prob. Chi-Square (15) is 0.1224, and Prob. The Scaled Explained SS of 0.7267 is entirely greater than the significance level of 0.05. The results show that Indonesia's coal exports are influenced by the dynamics of international coal prices, exchange rates, global interest rates, and China's economic activities as a major trading partner. The long-term and short-term coefficients obtained from the ARDL model show a pattern of relationships consistent with international trade theory and the empirical literature on energy commodity markets.

The results show that international coal prices have a significant positive impact, both in the short and long term, supporting the idea that global prices are shaped by international supply-demand interactions. These global market conditions also often show a high level of uncertainty due to factors such as the energy policies of major countries, global business cycles, and supply dynamics (Wang et al., 2024). In the case of Indonesia, the strong long-term

coefficient indicates that its position as the world's top exporter makes its exports highly sensitive to price fluctuations; This is a common trait of a commodity-dependent country.

The results also show that exchange rates have a significant negative effect on coal exports in the long run, which at first seems contrary to conventional theoretical predictions that the depreciation of the domestic currency will increase export competitiveness. However, findings like this are not uncommon in the primary commodity industry. Some studies show that commodity exports typically rely on long-term contracts, the use of imported inputs, and cost exposure in foreign exchange.

Depreciation can increase costs and decrease export volumes (Pane and Patunru, 2023). Thus, the negative impact of exchange rates on Indonesia's coal exports is likely to reflect the high import content of mining activities, including heavy machinery, fuel, and extraction technology. Explanations like this have also been observed in mineral commodities in other countries that have similar trade patterns.

In this study, the global interest rate, represented by the Federal Funds Rate (FFR), only had a short-term effect and was insignificant in the long term. This is in line with research that emphasizes that the physical demand of commodities is not always the driver of US monetary policy to the commodity market. Instead, it occurs through mechanisms such as liquidity conditions, capital costs, or changes in investor expectations (Ahmed, 2023). Since international coal trade relies heavily on long-term contracts between mining companies and global buyers, short-term interest rate changes in the United States do not necessarily affect Indonesia's export volume.

It was found that Indonesia's coal exports are highly dependent on China's economic growth, which yields great benefits both in the short and long term. As noted in the commodity trading literature, China has been a major driver of energy demand around the world, especially since the 2000s, when massive industrialization increased the use of coal for manufacturing, power generation, and logistics. China's energy consumption pattern, which is very sensitive to economic growth, showed a positive coefficient in this study. This means that Indonesia's exports as the main supplier of coal in East Asia will increase in line with China's economic growth.

The Error Correction Mechanism (ECT), which has a value of -1.351803 and is significant at a high confidence level, suggests that the model can adjust quickly to deviations from long-term equilibrium. An absolute value greater than one is not a model error, but indicates an over-adjustment, which is a condition in which a short-term adjustment exceeds the magnitude of the equilibrium deviation and only stabilizes itself in the following period. This is in line with dynamic coal market conditions and is influenced by global commodity prices, energy demand, decarbonization policies, and changes in supply from major exporting countries.

The results of the diagnostic tests on the model support the overall validity of the model. The absence of autocorrelation and heteroscedasticity ensures that the estimation is unbiased and efficient, while the residual normality results reinforce the feasibility of statistical inferences made on the model coefficients. The dynamics between variables do not overlap much, as shown by the low VIF values, which suggests that multicollinearity does not interfere with the interpretation of coefficients.

These results support the literature assertion that ARDL is an effective method for handling time-lapse data with complex characteristics, including energy commodity data that has high volatility (Avazkhodjaev, Dhiensiri and Rakhimov, 2024). Overall, the results of this study show that global factors, especially China's economic growth and international coal prices, determine Indonesia's coal exports. In contrast, the role of domestic macro variables, such as exchange rates, becomes more complex and contradicts the predictions of conventional export theory.

CONCLUSION

The results revealed that Indonesia's coal exports amid global economic volatility were primarily driven by external macroeconomic factors, particularly international coal prices and China's economic growth, with ARDL long-term estimates confirming a significant positive effect from price increases—reflecting sensitivity to global energy markets—and export patterns closely tied to China's demand as Asia's top fossil fuel consumer. Conversely, *Rupiah* depreciation against the US dollar exerted a significant negative long-term influence due to the mining sector's reliance on imported inputs, while US benchmark interest rates showed no significant impact, indicating indirect monetary policy transmission. These findings underscore Indonesia's vulnerability to uncontrollable external dynamics; to enhance stability, the government should diversify markets, boost operational efficiency, reduce import dependence, strengthen macroeconomic frameworks, develop early warning systems, secure long-term contracts, add value through clean coal technologies, and align with global energy transitions. For future research, scholars could extend the analysis by incorporating climate policy variables (e.g., carbon taxes) and renewable energy adoption rates to assess their disruptive potential on coal export trajectories.

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