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The Coal Price Shock and Its Impacts on Indonesian Macroeconomic Variables: An SVAR Approach

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Abstract

Purpose: Changes in energy prices can be considered as one of the factors of macroeconomic uncertainty. This study examines the impact of coal price shocks on Indonesian macroeconomic variables. **Research design, data and methodology:** The structural vector autoregressive model is used on monthly data from January 2010 to June 2023. **Results:** The impulse response functions indicate that coal price shocks have a negative impact on output and a positive impact on CPI (Consumer Price Index) and the effective real exchange rate. Following a shock in coal price growth, output growth takes twelve months, CPI growth takes fifteen months, and the effective real exchange rate takes seventeen months to reach equilibrium. Coal price growth shocks generally do not have a significant contribution to the variation in output, CPI growth and effective real exchange rate. On average over a twelve-month simulation, coal price growth shocks contribute 2.06 percent to output growth variation, 0.0042 percent to CPI growth variation, and 0.0046 percent to effective real exchange rate growth variation. **Conclusions:** This study finds that the impact of rising coal prices, as an energy source in Indonesia, can be offset by coal export revenues. This is possible considering that 70-80% of Indonesia's coal is exported.

Keywords : Coal Price, Structural VAR, Macroeconomy

JEL Classification Code : Q43, E31, C32, Q41

1. Introduction

Resources such as energy play a vital role in the economy. Energy flows through various sectors such as industry, transportation, agriculture, and households. In industry, energy is needed to run machinery and production equipment, while in transportation, vehicles and ships require energy to operate. In the agricultural sector, modern tools and food production require energy to function. Consumers use energy for household appliances, such as lighting, heating, and cooling. To maintain economic stability, a stable and affordable energy supply is needed.

The Russia-Ukraine war has led to energy supply problems for several major countries. The price spike occurred after many European countries lost access to key supplies from one of the large producers, Russia. Low energy supply will cause energy prices to rise. This is because the higher energy demand, the more difficult it is for producers to provide these energy needs. This condition can cause intense competition in the energy market and increase energy prices. Tight competition to meet energy

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needs in each country during the hot period of the Russia-Ukraine war caused quite large fluctuations in coal prices in Indonesia.

The fluctuating coal prices can have a significant impact on a country's economy. When energy prices rise, production costs will increase, so the prices of goods and services will also rise. This can cause inflation and reduce consumer purchasing power. Conversely, when energy prices fall, production costs will decrease, so the prices of goods and services will also fall. This can cause deflation and increase purchasing power. In the long term, fluctuations in coal prices can affect a country's economy. This is in line with Guo et al. (2016) who argue that changes in energy prices can be considered as a factor of macroeconomic uncertainty.

Furthermore, countries with very large coal exports will receive additional export revenues when coal prices rise, which will encourage the strengthening of the real effective exchange rate. Conversely, if coal prices fall, the country's export revenues will fall, which can negatively affect the real effective exchange rate. However, rising coal prices can also affect export competitiveness. High coal prices can increase production costs for industries that rely on it as a raw material, thus encouraging companies to reduce coal use or seek alternatives. This can reduce the competitiveness of the country's products in the international market. A decrease in competitiveness can result in a decrease in exports, which will affect the country's real effective exchange rate. This mechanism is very likely to occur in Indonesia considering that Indonesia's coal exports can be said to be quite large, which is around 70 to 80 percent of coal production (see Figure 1).

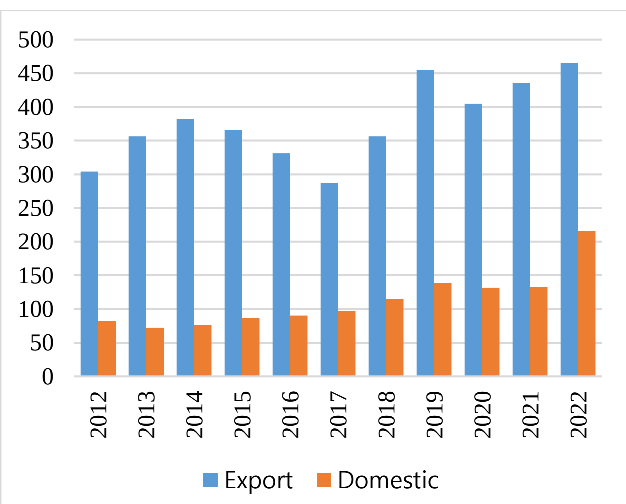

Figure 1: Comparison of Indonesian Coal Exports and Domestic Use, 2012-2022

During the period from 2012 to 2020, the final energy consumption in Indonesia for the commodity of oil fuel, which had the highest consumption in 2012, consistently experienced a decline each year. In contrast, for other commodities, there was fluctuation throughout the period, with a simultaneous decrease in consumption in 2022, except for the coal commodity. This can be observed in Figure 2, which provides an overview of the fluctuation in final energy consumption in Indonesia from 2012 to 2022.

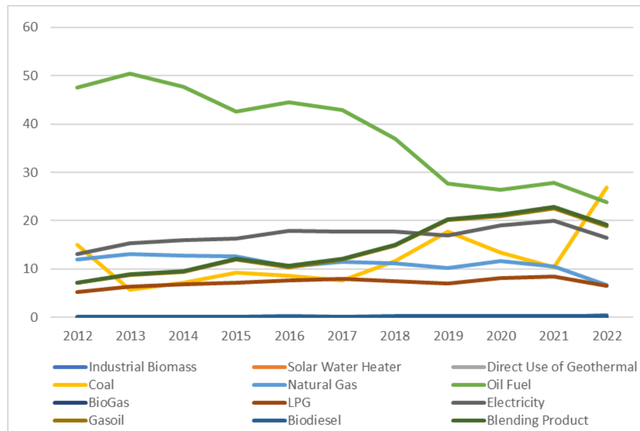

Figure 2: Indonesia's Final Energy Consumption 2012-2022

The upward trend in the final energy consumption of coal commodities provides valuable information that from 2012 to 2022, coal provides an energy supply that tends to continue to increase every year. Furthermore, if this trend continues in the future, there is a possibility of a shift in the dominance of primary energy commodities in fulfilling the national energy demand in Indonesia. This is evident from oil fuel, the current primary commodity, which has been experiencing a continuous decline each year. In fact, in 2022, the percentage of final energy consumption of coal commodities reached 26.87%, surpassing oil fuel, which had a percentage of 23.76%.

2. Literature Review

2.1. Mechanism of Coal Price Transmission

Fluctuations or shocks in the economy can occur due to changes in aggregate demand (demand shock) or changes in aggregate supply (supply shock), such as an increase in the prices of intermediate goods (Setiawan, 2010) such as coal prices.

The implications of the rise in coal prices on the economy, in general, can be understood through the mechanisms of demand and supply, which are translated through two transmission channels. First, the increase in coal prices will generate negative shocks on the supply side (negative supply-side shock). This means that the increase in coal prices will lead to higher expenditures for energy for businesses (industries), which, in turn, will affect the decisions of companies to increase the amount of production or, for certain companies, even reduce the amount of production.

Second, the increase in coal prices represents a fundamental shift in the terms of trade from coal-importing/ consumer countries to coal-exporting/ producer countries. Consequently, income and real spending in importing countries will decrease. Thus, the transmission of the increase in coal prices through these two channels will lead to a reduction in aggregate demand and aggregate supply, subsequently resulting in a decline in output or a weakening of economic growth. The impact of aggregate supply shocks on prices and output in an open economy can be graphically illustrated as shown in Figure 3.

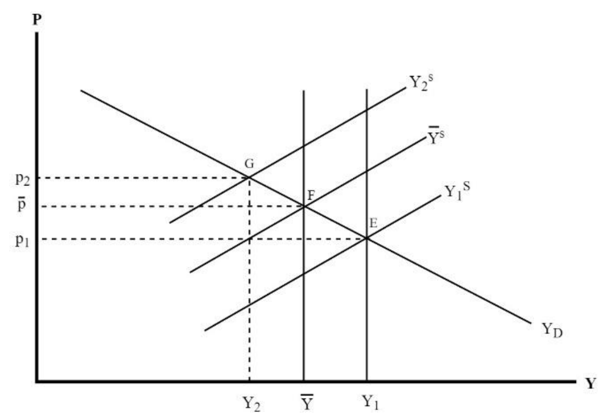

Figure 3: Stagflation Effects of Supply Shocks

Assuming there is an increase in the prices of intermediate goods such as fuel (assuming wage costs are fixed/rigid), this will raise production costs and the prices of domestic goods offered by producers, or there will be a leftward shift in the aggregate supply curve (from Y_0^s to Y_1^s). The implications of the impact of this price increase will reduce output, as illustrated by the change in the economic equilibrium from point E to G. In other words, the supply shock results in stagflation, a condition where the economy experiences stagnation (a decrease in output) and inflation (an increase in prices).

In the long term, there will be an adjustment in the equilibrium conditions of the economy. The effect of this price increase will impact the reduction of real wages (W/P). When employment contracts are renewed with lower nominal wages (under full employment conditions), there will be a rightward shift in the aggregate supply curve (from Y_1^s to $\bar{Y}^s$). The economic equilibrium will shift from point G to F rather than to point E. This is based on the idea that the increase in coal prices will lead to a sectoral cost adjustment for industries that primarily use coal as an energy source. In conclusion, it can be inferred that in the long term, aggregate supply shocks can lead to stagflation, a condition where the economy experiences stagnation (a decrease in output) and inflation (an increase in prices).

Furthermore, the specific effects of changes in energy prices on the performance of macroeconomic variables can be explained through six transmission mechanisms (Brown & Yücel, 2002). (1) Supply-side shock effect: addressing the direct impact of changes in marginal production costs and the reduction of company profits caused by energy price shocks on output; (2) Wealth transfer effect: discussing how changes in income distribution among societal groups can influence aggregate demand and economic growth; (3) Inflation effect: analyzing the relationship between domestic inflation and energy prices. Moreover, the increase in inflation as a result of this inflation effect is highly dependent on the pass-through inflation effect of world energy prices on domestic inflation, a country's policy, the country's reaction in tightening their monetary policies to curb inflationary pressures, consumers' reaction to a decrease in real income, and producers' efforts to increase profit margins; (4) Real balance effect: evaluating changes in money demand and monetary policy; (5) Sectoral adjustment effect: estimating adjustments in industrial costs, mostly used to explain the impact of oil price shocks; (6) Unexpected effect: focusing on the uncertainty of oil prices and their impacts.

2.2. Related Research, Hypothesis and Research Limitation

Research related to the impact of energy price shocks on the macroeconomic conditions of a country has been widely conducted. In general, these studies explain that energy price shocks are one of the factors contributing to macroeconomic uncertainty. The majority of studies examining the impact of changes in energy prices use oil prices as an external factor. This is because crude oil consumption constitutes the largest share of consumption in their respective countries. Examples of such research include studies conducted by Cologni and Manera (2008), Malik et al. (2017), Cunado et al. (2015), Ali Ahmed and Wadud (2011), Eryigit (2012), Du et al. (2010), Iwayemi (2011), Yildirim and Guloglu (2024), Maghyereh et al. (2024), Raj and Sharma (2024), and Yin (2024).

For example, a study conducted by Malik et al. (2017) aimed to evaluate the impact of oil price fluctuations on macroeconomic variables in Pakistan. This research employed the Structural Vector Autoregressive (SVAR) method to analyze monthly data from January 1990 to December 2015. The study's findings indicated that oil price fluctuations have a significant impact on macroeconomic variables in Pakistan, including economic growth, inflation, exchange rates, and interest rates.

Ali Ahmed and Wadud (2011) also conducted a study to analyze the impact of oil price shocks on macroeconomic activities in Malaysia, including industrial production and the Consumer Price Index. Additionally, the research evaluated the response of the central bank of Malaysia to oil price uncertainty. The methodology employed in this study was the Structural Vector Autoregressive (SVAR) model. The data used covered monthly observations from January 1991 to December 2016. The study's results indicated that oil price shocks have a significant impact on macroeconomic activities in Malaysia.

There is also research that uses coal prices as an external factor such as Guo et al. (2016), Acharya and Aruna (2020), and Yu et al. (2024). The study conducted by Yu et al. (2024) aimed to analyze the impact of energy shocks, specifically coal and oil shocks, on China's macroeconomy. To achieve this objective, the researcher employed an analytical method involving the Structural Vector Autoregression (SVAR) model. The data used included information on energy consumption, fixed asset investment, and various other macroeconomic variables in China, covering the period from 2006 to 2020. The findings indicated that energy shocks, both from coal and oil, had a significant impact on China's macroeconomy. The study revealed that energy price shocks could affect industrial output and overall economic stability.

Guo et al. (2016) conducted a study to investigate the relationship between changes in coal prices and inflation in China. The methodology employed was the vector autoregression (VAR) model and impulse response function analysis. The data used covered monthly time series from June 1998 to September 2014. The research findings indicated that the relationship between changes in coal prices and inflation is asymmetric. Negative changes in coal prices have a more significant impact on inflation than positive changes. This is because coal is a crucial input in many industries, and a decrease in coal prices can reduce production costs, thereby lowering the overall price level. Conversely, an increase in coal prices can raise production costs, leading to an increase in the overall price level.

Based on the related research and literature review presented, the researcher formulates three hypotheses. (a) Shocks in the coal reference price have a negative impact on the growth of output. (b) Shocks in the coal reference price have a positive impact on the growth of the Consumer Price Index (IHK). (c) Shocks in the coal reference price have a positive impact on the growth of the real effective exchange rate (REER).

The initial hypothesis of this research is that coal price shocks have a negative impact on output growth and a positive impact on the growth of the Consumer Price Index (CPI) and Real Effective Exchange Rate (REER).

The main limitation of this study is its focus on the direct effects of coal price volatility without fully considering broader environmental implications

3. Research Methods and Materials

3.1. Method

The analysis employed in this research comprises descriptive and inferential analyses using the Structural Vector Autoregressive (SVAR) model. This study employs the SVAR method as a dynamic analysis tool, enabling it to demonstrate the impact of changes in one variable on another. While this approach is widely used in international cases, it remains underutilized in analyzing the impact of coal in Indonesia.

The analysis in this study begins with pre-estimation testing, which includes stationarity testing and determining the optimal lag length. The next step is to estimate the SVAR. The SVAR model used in this study is adopted from Eric Parrado's model (Parrado, 2001) as cited in Setiawan (2010). The model is based on research conducted by Cushman and Zha (1997)and Kim and Roubini (2000). The selection of Eric Parrado's model is made due to the similarity in characteristics between the research objects, whereas Chile, similar to Indonesia, follows the principles of a small open economy and a floating exchange rate system. With the four variables mentioned earlier, the SVAR model in this study can be expressed as follows:

$$\boldsymbol{B_0 Y_t} = \boldsymbol{B(L) Y_{t-L}} + \boldsymbol{B e_t} \tag{1}$$

Where Yt is a vector with 4 research variables, B0 represents contemporaneous relations among the variables, B(L) is a finite-order matrix polynomial with the lag operator L. B is a matrix with a non-zero diagonal, and e_t is a vector of structural disturbances.

The restrictions in the SVAR model used in this study are formed based on assumptions found in the model proposed by Eric Parrado (Parrado, 2001) as cited in Setiawan (2010). Thus, the framework of the SVAR model in this research can be expressed as follows:

$$\begin{bmatrix} e_{hba} \\ e_y \\ e_{ihk} \\ e_{reer} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{21} & 1 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 1 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & 1 \end{bmatrix} \begin{bmatrix} u_{hba} \\ u_y \\ u_{ihk} \\ u_{reer} \end{bmatrix} \tag{2}$$

Where the vector e represents structural disturbances and the vector u represents residual shocks for each respective variable. The equations in the first row indicate the influence of the coal reference price shock on the coal reference price itself. The variable coal reference price is an external variable not influenced by simultaneous changes in domestic variables. The equations in the second row show the assumed impact of domestic output shock influenced by the coal reference price shock and the domestic output shock itself, while the variables of the price level and real effective exchange rate do not directly affect the output. This is based on the assumption that companies do not immediately change or increase production due to adjustment costs. The equations in the third row indicate that the price level shock is influenced by the coal reference price shock, domestic output, and the price level shock itself simultaneously. The equations in the fourth row show that the shock to the real effective exchange rate is influenced by simultaneous changes in all variables, namely coal prices, domestic output, price level, and real effective exchange rate.

After estimating the SVAR, model stability is checked through AR Roots to ensure the validity of the impulse response function (IRF) analysis. The final step is to analyze the IRF of the generated model.

The Impulse Response Function (IRF) is an analytical tool in the Vector Autoregression (VAR) model used to measure the impact of changes in one variable on another over a specified period. The IRF illustrates how endogenous variables respond to exogenous impulses (shocks) in one or more variables within the system. These exogenous impulses can include phenomena, changes in economic policies, market conditions, or other events affecting variables in the system. The IRF shows the effect of shocks from one variable on another over time, allowing for the observation of impacts until equilibrium is reached. When an exogenous shock of one standard deviation occurs in an independent variable, the IRF is used to examine the contemporary effects among variables (Munandar, 2018) . Additionally, the IRF can reveal how long the impact of a shock from one variable on another will persist (Enders, 2008).

Forecast Error Variance Decomposition (FEVD) is an analytical tool in the Vector Autoregression (VAR) model used to measure the contribution of each variable in the system to the variance of forecast errors for endogenous variables over a specified period. FEVD decomposes the forecast error variance of endogenous variables into components attributable to each variable within the system. According to Enders (2008), FEVD indicates the importance of each variable when shocks occur, allowing for the estimation of the percentage contribution of variance if a particular variable changes. FEVD can also be used to test hypotheses about causal relationships between variables in the system and to forecast the impact of economic policies on economic variables.

3.2. Data and Collection Methods

The data utilized in this research is secondary data in the form of a time series, covering monthly periods from January 2010 to June 2023.

Time series data is a collection of data ordered by time or gathered periodically from one period to the next, such as daily, weekly, monthly, or yearly. Time series data plays a crucial role in decision-making processes as it allows us to analyze data patterns over time. This helps in making predictions or projections about future events. The fundamental assumption in using time series data is that patterns observed over several past periods are likely to influence or repeat in the present.

The data is sourced from various institutions, both at the national and international levels, with the following details:

Monthly coal reference prices are obtained from the publication of the Ministry of Energy and Mineral Resources of Indonesia. The Coal Reference Price (Harga Batubara Acuan or HBA) is the average price of coal used as a reference in determining the selling price of coal by mining companies. The coal reference price is expressed in USD per ton.

Output data is obtained from the publication of the Central Statistics Agency (Badan Pusat Statistik or BPS). Indonesia's output is depicted through the Gross Domestic Product (GDP) at constant prices, with the base year being 2010. Output represents the value added of goods and services produced by all economic units in a country, calculated using prices prevailing in a specific year as the base. Output is expressed in Trillions of Rupiah. BPS publications have quarterly periods, which are then interpolated to a monthly format using the proportional Denton method with the guiding variable being the industrial production index released by Bank Indonesia. The use of the proportional Denton method follows the approach used by the IMF for interpolation (Marini & Di Fonzo, 2012). Furthermore, the reason for using the industrial production index as the guiding variable is because it is a coincident variable of the output variable. This is supported by research conducted by Syarifuddin et al. (2009) in the Economic and Monetary Bulletin published by Bank Indonesia.

Monthly Consumer Price Index (IHK) data is obtained from BPS publications. The Consumer Price Index in this study uses the year 2018 as the base year. IHK is expressed in the form of index numbers.

Monthly effective real exchange rate data is obtained from the publication of the Bank for International Settlements. The effective real exchange rate is expressed in the form of index numbers.

4.2. Inferential Analysis

4.2.1. Stationarity Test

The testing for stationarity in this study utilized the unit root test with the Phillips-Perron (PP) method. If the probability value (p-value) from the PP test is smaller than the significance level (0.05), then the series is considered stationary at that level. A summary of the stationarity testing results is as follows:

Table 1: Results of Stationarity Testing of Research Variables

Variables	Level		*First Difference*	
	PP Test	Probability	PP Test	Probability
Coal price (reff)	-0,13643	0,6352	-12,667	0,0000
Output	3,601823	0,9999	-29,577	0,0000
CPI	7,717101	1,0000	-6,9780	0,0000
REER	-0,25368	0,5934	-10,568	0,0000

From Table 1 above, we can observe that at the level, all variables have a unit root or are non-stationary. However, testing at the first difference level indicates that all research variables are stationary at a significance level of 0.05. Based on these testing results, the estimated VAR equation is conducted in the first difference form.

4.2.2. Optimum Lag Length

The determination of lag length is used to ascertain the duration of the interdependence period of a variable with its past values and other endogenous variables. The optimal lag length is determined based on five criteria: sequential modified LR test statistics (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ). The comprehensive results of the VAR Lag Order Selection can be seen in the following table.

Table 2: Optimum Lag Determination Results

Lag	LR	FPE	AIC	SC	HQ
0	NA	1,85e+11	37,29268	37,37122	37,32458
1	82,08238	1,31e+11	36,95191	37,34461*	37,11142
2	75,25756	9,64e+10	36,64290	37,34976	36,93001*
3	28,34331	9,72e+10	36,64975	37,67077	37,06447
4	19,99207	1,04e+11	36,71133	38,04651	37,25365
5	42,88613*	9,27e+10*	36,59774*	38,24708	37,26766
6	20,22722	9,80e+10	36,64860	38,61210	37,44613

* indicates lag order selected by the criterion

Based on Table 2, the optimal lag according to the criteria LR, FPE, and the smallest AIC is lag 5, as indicated by the asterisk (*). This implies that 3 out of the 5 criteria used provide information that lags 5 is the optimum lag. Therefore, for subsequent estimations, lag 5 will be used in the VAR equation model.

4.2.3. SVAR Model Estimation

Before estimating the SVAR model, the VAR approach is first employed. Based on the previous discussion regarding data stationarity testing and the determination of the optimal lag, the VAR estimation is conducted for 4 variables at the first difference level with a lag length of 5. This results in obtaining 20 coefficients for each equation, or a total of 80 coefficients (20 x 4) for the regression equations.

Following the VAR estimation, certain restrictions are imposed based on the variables used in the study, as previously explained in equation (2). The results of the SVAR estimation are presented in Table 3.

$$\begin{bmatrix} e_{hba} \\ e_y \\ e_{ihk} \\ e_{reer} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ C(1) & 1 & 0 & 0 \\ C(2) & C(4) & 1 & 0 \\ C(3) & C(5) & C(6) & 1 \end{bmatrix} \begin{bmatrix} u_{hba} \\ u_y \\ u_{ihk} \\ u_{reer} \end{bmatrix}$$

Table 3: The Results of SVAR Restrictions Estimation

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-0.152252	0.006299	-24.17096	0.0000
C(2)	-0.001171	0.006299	-0.185864	0.8526
C(3)	-0.004113	0.010642	-0.386514	0.6991
C(4)	-0.001091	0.002359	-0.462707	0.6436
C(5)	-0.011359	0.003985	-2.850107	0.0044
C(6)	1.361724	0.234630	5.803697	0.0000

Based on the results of the SVAR estimation, it can be generally observed that the variables used as innovations from the restrictions in the model have a statistically significant impact on other variables. This can be seen from the probabilities below the 5% significance level for three of the six restrictions imposed. However, the SVAR model results will not be analyzed in-depth because the determination of the SVAR model, in this case is only intended to produce unbiased regression. Interpretation of individual coefficients in VAR/SVAR systems is rarely done due to the complexity of the model, and analysis is often conducted through Impulse Response Functions (IRF) and Forecast Error Variance Decomposition (FEVD) results (Gujarati & Porter, 2009). Therefore, to address the research objectives, the focus will be on the IRF and FEVD results.

4.2.4. Model Stability Test

The established SVAR model needs to undergo a stability check. The analysis of the impulse response function and variance error forecast decomposition will become invalid if performed on an unstable model.

The stable condition requires that the SVAR model formed has characteristic roots within the unit circle. From the obtained results, it can be concluded that the formed SVAR model is stable because it has characteristic roots below one, making it valid for use in the IRF and FEVD analysis processes. The testing results can be viewed in Figure 4 and Table 4.

Table 4: Modulus Values from Stability Test Results

Root	Modulus
-0.781268 + 0.406488i	0.880689
-0.781268 - 0.406488i	0.880689
-0.556401 + 0.638886i	0.847206
-0.556401 - 0.638886i	0.847206
0.365817 + 0.742036i	0.827308
0.365817 - 0.742036i	0.827308
0.224370 - 0.729211i	0.762949
0.224370 + 0.729211i	0.762949
0.737177	0.737177
0.363146 - 0.601715i	0.702806
0.363146 + 0.601715i	0.702806
0.698108	0.698108
-0.355263 - 0.575690i	0.676484
-0.355263 + 0.575690i	0.676484
-0.632163	0.632163
-0.144862 - 0.604728i	0.621836
-0.144862 + 0.604728i	0.621836
0.369608 + 0.227643i	0.434087
0.369608 - 0.227643i	0.434087
0.230596	0.230596

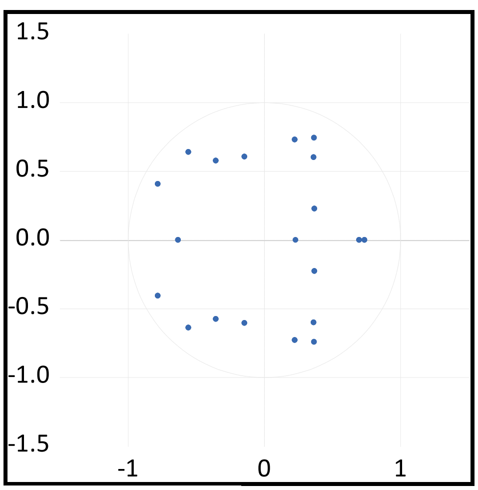

Figure 4: Visualization of Modulus Values from Stability Test Results

4.2.5. Impulse Response Function

The analysis of Impulse Response Functions (IRF) is based on the values of IRF coefficients, which depict information about the magnitude of the response of one endogenous variable to a one-standard-deviation change in all endogenous variables. In other words, it reveals the short-term and long-term impacts caused by a one-standard-deviation change in one endogenous variable on all endogenous variables in the SVAR model.

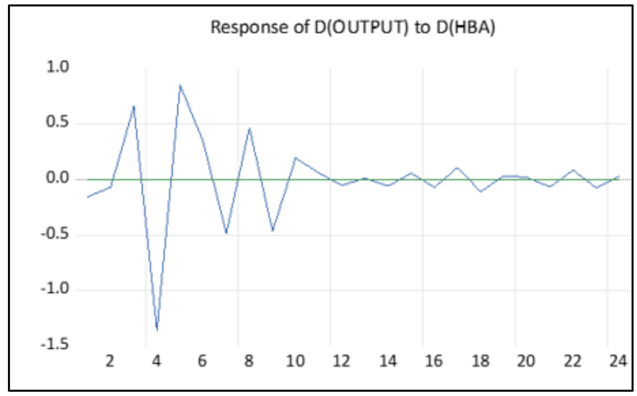

Figure 5: Impulse Response Output to HBA shock

Through Figure 5, it can be seen how changes in output, Consumer Price Index (CPI) and real effective exchange rate respond to shocks in the growth of the Indonesian coal reference price. Indonesia's output response will continue to fluctuate between positive and negative from the first month to the twelfth month, with the magnitude of the response decreasing as time goes by. It can be said that output will reach equilibrium conditions in the twelfth month.

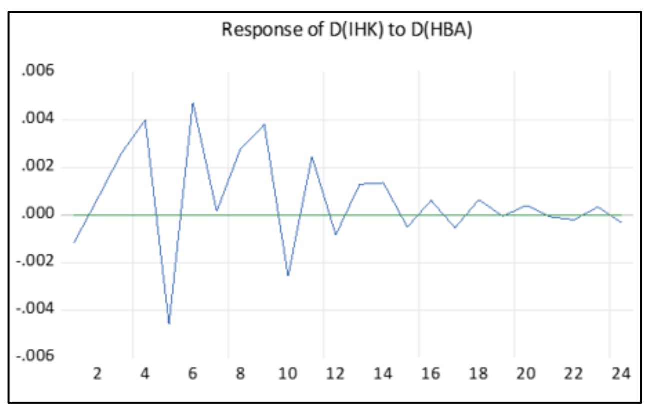

Figure 6: Impulse Response CPI to HBA shock

The CPI's negative response to shocks to the growth of the reference coal price only occurred in the first month at the beginning of the period. This can be seen in Figure 6. In the second month, the CPI response to changes in coal reference price shocks became positive. This positive response only lasted for three months from the second period with the response level getting bigger and becoming negative again in the fifth month. However, this negative response lasted only in the fifth month and became positive again in the sixth month with the magnitude of the response alternating between positive and negative with the magnitude of the response getting smaller, so it can be said that the CPI will reach an equilibrium condition in the fifteenth month.

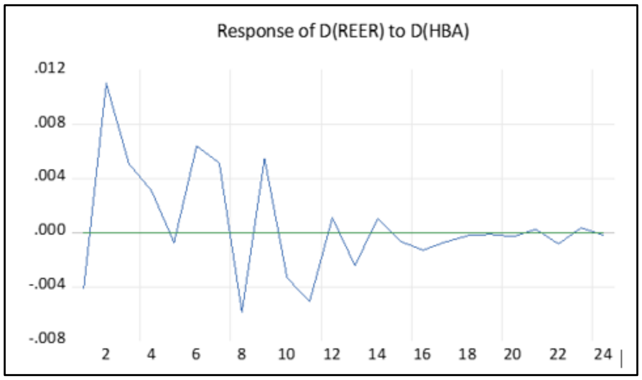

Figure 7: Impulse Response REER to HBA shock

Based on Table 7, the real effective exchange rate will respond negatively in the first month. In the second month, the real effective exchange rate response to coal price growth shocks showed a positive response. This positive response lasted until the fourth month with the magnitude of the changes getting smaller. In the seventeenth month, the response to changes in the real effective exchange rate to the coal price growth shock approached zero so that it can be said that the real effective exchange rate reached an equilibrium condition in the seventeenth month.

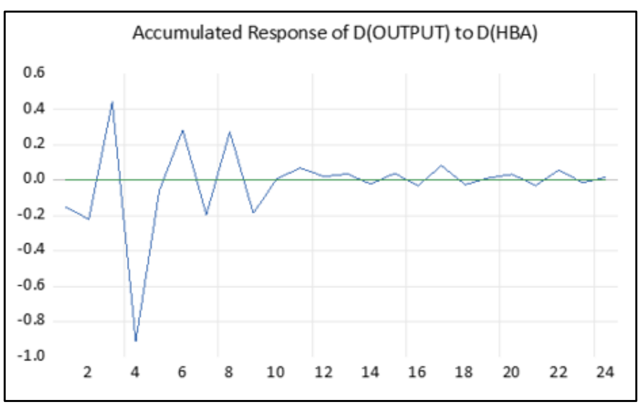

Figure 8: Accumulated Impulse Response Output to HBA shock

The cumulative Impulse Response Functions (IRFs) presented in Figure 8 align with the initial hypothesis of the research, which posits that changes in output respond negatively to the shock of Indonesia's coal reference price growth. This corresponds to the theory proposed by Brown and Yucel (2002) in the first channel, where a supply shock leads to stagflation (stagnation and inflation). When there is an increase in the prices of intermediate goods, it raises production costs and the prices of domestic goods offered by producers, causing a leftward shift in the aggregate supply curve. The implications of the impact of price increases will reduce output. In other words, a supply shock results in stagflation, where the economy experiences both stagnation (output decline) and inflation (price increase).

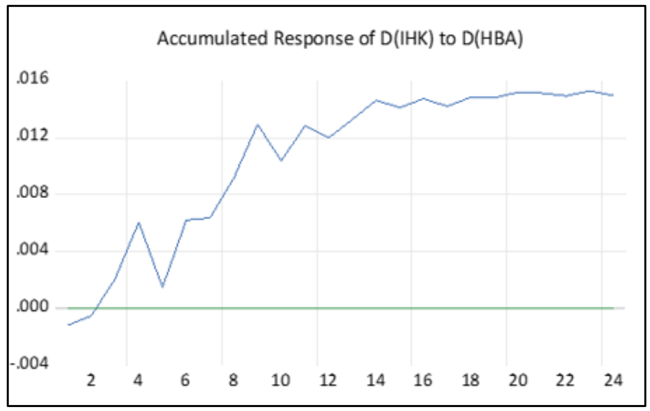

Figure 9: Accumulated Impulse Response CPI to HBA shock

The cumulative IRF of the Consumer Price Index (CPI) presented in Figure 9 supports the initial hypothesis of the research, indicating that changes in CPI respond positively to the shock of Indonesia's coal reference price growth. This can occur because an increase in the coal reference price leads to higher prices needed to supply energy, such as electricity and other forms of energy. The rise in energy prices will affect the prices of goods and services that use energy in their production processes. The increase in the prices of goods and services will lead to a decrease in the purchasing power of the population, ultimately increasing the CPI. The positive response of CPI due to the shock in energy price growth aligns with the Inflation Effect channel in the energy price transmission theory developed by Brown and Yucel (2002).

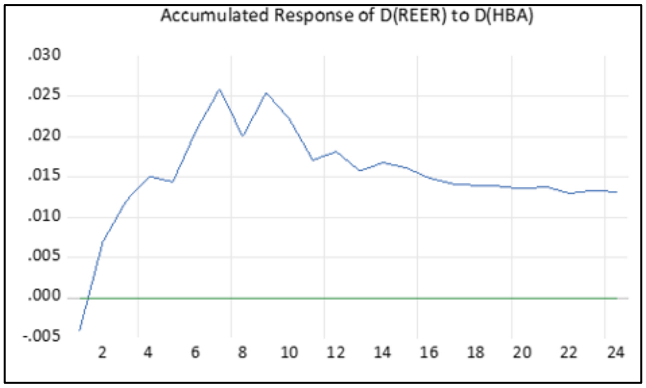

Figure 10: Accumulated Impulse Response REER to HBA shock

The cumulative IRF presented in Figure 10 in line with the initial research hypothesis, that changes in the real effective exchange rate respond positively to shocks to the growth of Indonesia's reference coal price. This can be connected to the purchasing power parity theory. This theory states that the exchange rate between two currencies should reflect the relative prices of the same basket of goods and services in the two countries. An increase in coal prices in one country will increase the overall price level in that country, because higher production and distribution costs will be reflected in the prices of other goods and services. According to purchasing power parity theory, an increase in the price level in one country will cause that country's currency to depreciate. In other words, shock changes in coal prices indicate a weakening effect on the real exchange rate of the domestic currency, so that when coal prices increase the price level and exchange rate of the domestic currency, this can reduce a country's real effective exchange rate. However, when income from coal exports increases more than the impact of price increases, this will cause an increase in the purchasing power of the domestic currency in the international market which will ultimately create positive pressure on the real effective exchange rate in the country. The positive response shown in the cumulative IRF graph for the real effective exchange rate response to coal prices indicates that Indonesia's coal export revenues as a coal exporting country are able to match the impact of the increase in coal prices that occurred.

4.2.5. Forecast Error Variance Decomposition

Using FEVD (Forecast Error Variance Decomposition) analysis, it can be determined what percentage of the variation in an endogenous variable is explained by each disturbance present in the applied SVAR model. In other words, FEVD analysis is used to identify which variables play the most significant role in explaining the changes in a particular variable. Tables 5 through 7 show the percentage of variation in each endogenous variable caused by shocks from other variables. From the FEVD results, it can be concluded that the variation in each variable is predominantly determined by the variable itself, with varying magnitudes.

Table 5: Results of FEVD Output

Month	S.E.	D(HBA)	D(Output)	D(IHK)	D(REER)
1	1,012	2,266	97,734	0,000	0,000
2	2,350	0,500	28,051	27,403	44,046
3	5,604	1,486	4,949	41,553	52,011
4	8,324	3,327	2,312	50,917	43,444
5	8,800	3,920	2,077	47,584	46,418
6	9,042	3,857	1,967	50,192	43,984
7	9,405	3,827	1,820	46,462	47,892
8	15,250	1,550	0,693	77,621	20,136
9	19,004	1,057	0,446	85,394	13,103
10	19,020	1,066	0,446	85,344	13,144
11	19,831	0,982	0,410	86,451	12,158
12	20,346	0,933	0,390	87,062	11,615

Table 5 presents the FEVD values with a 12-month simulation following a shock to the output variable. Generally, an important source of variation in output changes is the shock from changes in the Consumer Price Index (CPI). In the first month, it is observed that the shock to output accounts for nearly all (97.73 percent) of the fluctuation in its own variation, while the remainder is attributed to changes in coal prices. During this month, the CPI and Real Effective Exchange Rate (REER) have not yet contributed to the variation in output changes.

By the second month, shocks from the CPI and REER variables begin to contribute to the variation in output changes. The shocks to coal price growth, CPI, and REER contribute 0.5 percent, 27.40 percent, and 44.04 percent, respectively, to the variation in output changes, with the remainder stemming from the output itself.

The role of shocks in coal price growth in explaining the variation in output changes peaks at 3.92 percent in the fifth month. After the fifth month, the contribution from coal price growth shocks to the variation in output growth steadily decreases until the end of the simulation period in the twelfth month. This also indicates that the fifth month marks the peak contribution of coal price shocks to output. In the final period of the simulation, the twelfth month, the shocks to coal price growth, CPI, and REER contribute 0.93 percent, 87.06 percent, and 11.61 percent, respectively, to the variation in output changes, with the remainder still coming from output itself.

Table 6: Results of FEVD CPI

Month	S.E.	D(HBA)	D(Output)	D(IHK)	D(REER)
1	1,000	0,000	0,000	100,000	0,000
2	1,092	0,000	0,000	99,999	0,000
3	1,101	0,001	0,000	99,977	0,022
4	1,117	0,002	0,000	99,975	0,022

5	1,129	0,004	0,000	99,951	0,045
6	1,136	0,005	0,000	99,926	0,069
7	1,162	0,005	0,000	99,927	0,068
8	1,163	0,006	0,000	99,920	0,074
9	1,170	0,007	0,001	99,919	0,073
10	1,173	0,007	0,001	99,917	0,076
11	1,174	0,007	0,001	99,911	0,081
12	1,176	0,007	0,001	99,911	0,081

Table 6 presents the FEVD values with a 12-month simulation following a shock to the Consumer Price Index (CPI) variable. Generally, the primary source of variation in CPI changes is the shock from changes in the CPI itself. In the first month, it is observed that the shock to the CPI accounts for the entire fluctuation (100 percent) in its own variation. By the third month, shocks from coal price growth contribute 0.001 percent, and the Real Effective Exchange Rate (REER) contributes 0.022 percent, with the remainder stemming from changes in the CPI itself. During this month, output has not yet contributed to the variation in CPI changes.

The role of shocks in coal price growth in explaining the variation in CPI changes remains minimal, ranging from 0.001 to 0.007 percent. Based on the 12-month simulation, the ninth through twelfth months represent the period with the highest contribution of coal price shocks to the CPI, at 0.007 percent.

In the final period of the simulation, the twelfth month, the fluctuation caused by shocks to the CPI remains high, at 99.91 percent, while the percentage of CPI fluctuation caused by shocks from coal prices, output, and REER does not show a significant increase.

Table 7: Results of FEVD REER

Month	S.E.	D(HBA)	D(Output)	D(IHK)	D(REER)
1	1,690	0,001	0,005	64,962	35,033
2	1,729	0,005	0,004	64,877	35,114
3	2,149	0,004	0,004	75,650	24,342
4	2,239	0,003	0,004	77,325	22,668
5	2,246	0,003	0,004	77,453	22,539
6	2,253	0,004	0,005	77,530	22,461
7	2,254	0,005	0,005	77,539	22,451
8	2,254	0,005	0,005	77,499	22,491
9	2,256	0,006	0,005	77,543	22,447
10	2,257	0,006	0,005	77,550	22,439
11	2,258	0,007	0,005	77,559	22,429
12	2,258	0,007	0,005	77,561	22,428

Table 7 presents the FEVD values with a 12-month simulation following a shock to the Real Effective Exchange Rate (REER) variable. Generally, the main sources of variation in REER changes are shocks from changes in the Consumer Price Index (CPI) and REER itself. In the first month, it is observed that the shock to REER accounts for 35.03 percent of its own variation, while the remainder is sourced from other variables. During this month, coal prices, output, and CPI already contribute to the variation in REER changes, although their contributions are still minimal.

In the following month, shocks from the CPI variable start to have an increasingly significant impact on the variation in REER changes. In the second month, shocks to coal price growth, output, and CPI contribute 0.005 percent, 0.004 percent, and 64.87 percent, respectively, to the variation in REER changes, with the remainder coming from changes in REER itself.

The role of coal price growth shocks in explaining REER variation remains small, ranging from 0.001 to 0.007 percent. Based on the 12-month simulation, the eleventh and twelfth months are the periods with the highest contribution of coal price shocks to REER, at 0.007 percent.

In the final period of the simulation, the twelfth month, the shocks to coal price growth, output, and CPI contribute 0.007 percent, 0.005 percent, and 77.56 percent, respectively, to the variation in REER changes, with the remainder coming from REER itself.

5. Conclusions

Based on the research findings on the volatility of coal prices and its impact on macroeconomic variables such as output, consumer price index, and effective real exchange rate, several conclusions can be drawn. (1) In general, the volatility of Indonesia's coal prices during the observation period ranged from 70 to 130 USD per ton under normal conditions in the global energy market, specifically from 2010 to 2020. However, during the Russia-Ukraine war that shook the energy market, the coal reference price reached its highest point, hitting 330.97 USD per ton. (2) The research results align with the initial hypothesis, indicating that the shock in coal price growth generally has a negative impact on output and a positive impact on the Consumer Price Index (CPI) and effective real exchange rate. Following the shock in coal price growth, it takes twelve months for output growth to return to equilibrium, fifteen months for CPI growth, and seventeen months for the effective real exchange rate to reach an equilibrium state. This research provides information that in Indonesia, Indonesia's coal export revenues as a coal exporting country are able to match the impact of the increase in coal prices that occurred. (3) Shocks in coal price growth generally do not have a significant contribution to the variation in output growth, the Consumer Price Index (CPI), and the Real Effective Exchange Rate (REER).

Coal is a source of energy that is full of pros and cons because it causes problems in the environmental sector so it is necessary to consider the negative impacts of its use, therefore it is recommended that further research consider the concept of green economy in modeling to explore how transitioning to more sustainable energy sources can mitigate the negative environmental impacts associated with coal use. Additionally, examining the role of government policies and international market dynamics could provide deeper insights into the relationship between coal prices and macroeconomic stability.

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