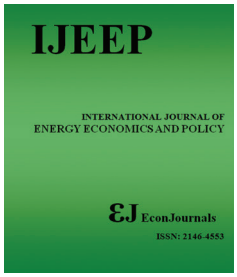

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Asymmetric Effects of World Energy Prices on Inflation in Indonesia

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ABSTRACT

This study analyzes the asymmetric effect of changes in world energy prices, which include crude oil, natural gas, and coal prices, and the exchange rate on consumer price index (CPI) inflation in Indonesia. The models used in the analysis are quantile regression and dynamic ordinary least squares. The period studied is monthly in the period 2001M01-2022M12. The study results show that world crude oil prices have asymmetrically positive effects on CPI inflation when world oil prices increase and decrease. The fall in the price of crude oil has a more significant effect than the increase. The asymmetric impact of world crude oil prices on CPI inflation was also found between lower and middle quantiles. However, the short-run impact of rising crude oil prices is only found in the 7th quantile. So, the long-run effect is more dominant than the short-run effect. The role of the fuel subsidy policy, which the government manages, is beneficial in reducing inflationary fluctuations originating from fluctuations in world crude oil prices. Efforts to develop oil refineries in Indonesia that need to be done to reduce imports of crude oil and fuel are expected to be able to reduce the impact of world oil price fluctuations on domestic inflation in the future.

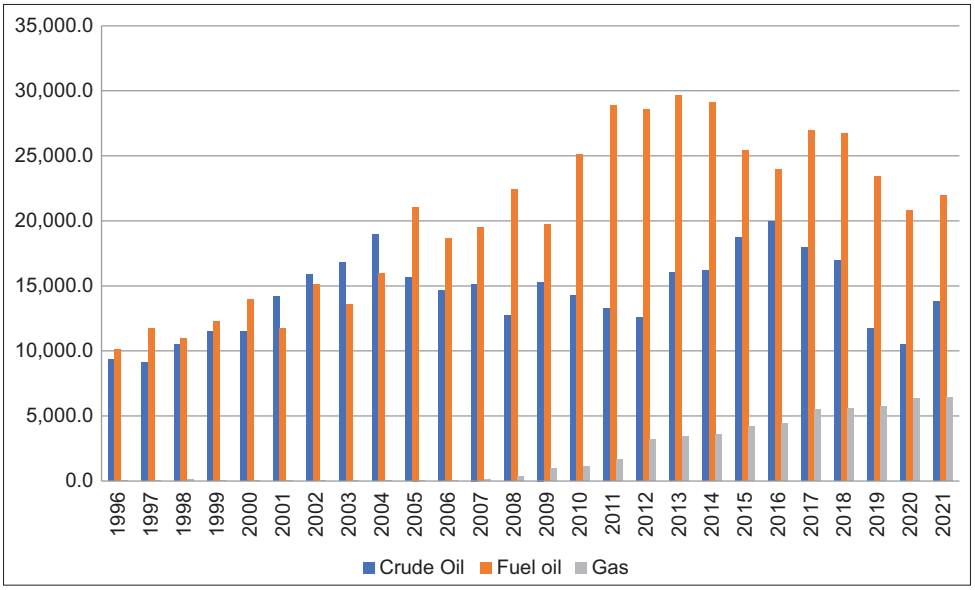
Keywords: Asymmetric Effect, CPI Inflation; Quantile Regression, World Crude Oil Prices, Fuel Subsidy Policy
JEL Classifications: C21; E31; Q41

1. INTRODUCTION

Today, energy issues are increasingly studied intensively and broadly with various interdisciplinary sciences. Energy issues have been extensively studied, starting from aspects of energy utilization that have an impact on economic growth (e.g., Mahalik and Mallick, 2014; Sek, 2017; and Purnomo et al., 2023) and environmental degradation (e.g., Zakari et al., 2021; Supriyanto et al., 2022; and Yuliadi and Wardani, 2023) and to what extent energy prices impact energy consumption (e.g., Chen, et al., 2016; Valizadeh et al., 2018; and Guan et al., 2023) and changes of domestic prices (e.g., Ayisi, 2021; Rizvi and Sahminan, 2020; and Kecek, 2023). One of the interesting issues related to the study of energy prices is their relation to monetary issues, mainly changes in domestic prices and inflation. Implementing inflation targeting in oil-importing countries is increasing policymakers' awareness about changes in global energy prices. Changes in energy prices have an impact on the pass-through in domestic inflation. So, the issue of the impact of changes in global energy prices, particularly oil prices, on the macroeconomic performance of oil-importing countries has recently attracted increasing attention to researchers and policymakers. The macroeconomic performance that generally gets the most attention from the impact of changes in oil prices is inflation, in addition to economic growth.

Indonesia is a net oil importing country, besides still importing natural gas and coal. Figure 1 shows the existence of Indonesia's imports of crude oil, fuel, and gas, which, although fluctuating, have tended to increase since 1996, especially fuel and gas. Crude oil, natural gas, and coal are the primary energies contributing to

Figure 1: Indonesia's oil and gas imports (thousand tons)



Source: Statistics Indonesia, 2022

Indonesia's top three, excluding biomass (Ministry of Mineral and Energy Resource Republic of Indonesia, 2020). The three types of primary energy are still imported from other countries to meet domestic energy needs. Since 2013 Indonesia's crude oil imports have been greater than its exports.

Meanwhile, for oil products, Indonesia has experienced excess imports from its exports since 1997. For natural gas, Indonesia has so far experienced positive net exports. However, the increase in natural gas imports occurred continuously. Meanwhile, as one of the largest coal exporters, Indonesia still imports coal to meet the demand for steel production, mining processing, and refining (smelters).

The most extensive use of final energy, especially oil, comes from transportation, followed by industry and households. These three are the top three sectors of final energy users in Indonesia. Therefore, based on the facts, the effect of changes in crude oil, natural gas, and coal prices on inflation in Indonesia is urgent, considering that Indonesia still imports these three types of energy.

Empirically, the impact of the increase in world oil prices on CPI inflation was more significant for oil-importing countries than for oil-exporting countries. A study conducted by Sek (2019) reveals this fact. However, the impact of changes in world energy prices on domestic inflation may vary from one country to another and in different periods. Pass-through of global commodity prices, including energy prices, to producer prices, according to research by Jiménez-Rodríguez and Morales-Zumaquero (2022), is more clearly found in advanced and emerging countries, while pass-through to consumer prices is less clear. However, energy prices best explain the variability of producer and consumer prices. Meanwhile, policymakers in countries that pay attention to inflation dynamics view the importance of passing through world commodity prices, especially food, and energy, to consumer prices. Although in a study by Conflitti and Luciani (2019), the pass-through of oil prices into core inflation is small, it lasts a long time. However, the pass-through effect of world oil prices on domestic prices cannot always be assumed to be symmetrical; that is, an increase in oil prices has an equal effect with a decrease in prices. The existence of rigidity in price behavior and the implementation of fuel price regulations and subsidies can have an asymmetric effect on changes in oil prices on consumer prices. Sek (2019) reveals that world oil prices can pass asymmetrically into CPI inflation. This study focuses on changes in oil prices to the CPI in both oil-exporting and importing countries. Oil price changes affect the increase in the CPI, and the indirect effect is more dominant than the direct effect. Meanwhile, Akinsola and Odhiambo (2020) argue that rising world oil prices reduce economic growth in low-income oil-importing countries.

Most of the previous studies focused on changes in oil prices as a proxy for energy prices. Likewise, the asymmetric effects investigated only focus on the asymmetric effect between rising and falling oil prices. Given the main primary energy use besides oil as well as the use of natural gas and coal in Indonesia as a country with a large population, a study is needed to analyze the impact of changes in global energy prices, which include crude oil, natural gas, and coal on changes in consumer prices asymmetrically. It is also necessary to analyze the asymmetric effects at various consumer price levels, bearing in mind that changes in the CPI are very dynamic in line with changes in global energy prices. This study analyzes the asymmetric effects of changes in oil prices using quantile regression and dynamic ordinary least squares (DOLS) models.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Energy is a primary input whose price increase will significantly impact economic sectors and the economy as a whole. With a flexible exchange rate, changes in global energy prices are a source of external shocks that impact the domestic economy, including

inflation. A study by Kecek (2023) provides empirical results that the most sensitive response of the Croatian domestic economy is to energy price shocks compared to other sources of supply shocks, such as increases in wages and prices for imported goods and services. The relative change in energy prices influencing domestic inflation is evident through the industrial sector's energy consumption. Yan and Bian (2023) state that rapid changes in energy prices positively impact inflation when energy consumption in the industrial sector in China overgrows. Rizvi and Sahminan (2020) empirically prove that oil and energy prices significantly impact domestic inflation in Brazil, Russia, India, Indonesia, China, and South Africa. Domestic adjustments within the inflation targeting framework are needed in response to world commodity price fluctuations.

Ayisi (2021) states that domestic inflation asymmetrically responds to world crude oil price changes. Due to this asymmetric effect, welfare costs increase with the inflation rate. Bawa et al. (2020) provide empirical evidence that the asymmetric effect of oil prices on inflation can be through headlines, core, and food inflation. An increase in oil prices leads to an increase in inflation, while a decrease in oil prices can reduce the marginal cost of production, thereby reducing inflation to moderate inflation.

Babuga and Naseem (2021) obtained empirical findings that there is an asymmetric effect of changes in oil prices on inflation in Sub-Saharan African countries. An increase in oil prices has a more significant effect on inflation than a decrease in oil prices. Oil as a vital input in production will push prices which have a more significant effect on inflation. Bala and Chin (2018) explain their findings that the asymmetric impact of oil prices is characterized by a difference in the positive impact between rising oil prices and decreasing them. The impact of the decline in oil prices on inflation is more significant than the increase. Subsidies in food and fuel prices have resulted in rigid price adjustments.

The empirical funding of a study by Binder (2018) states that gas price inflation affects expectations of non-gas inflation. This result implies that an increase in gas prices could trigger expectations of non-gas inflation and impact core inflation. Zhang et al. (2017) found empirical findings that an increase in natural gas prices led to an increase in the CPI. Rising natural gas prices substantially impact the chemical industry in the process of inflation. In addition, a study by Jalaee (2021) showed that although it was relatively low, rising natural gas prices impacted inflation.

Guo et al. (2016) presented their findings that coal prices positively impact both increasing and decreasing prices on CPI. The decline in coal prices had a more significant impact on the decline in CPI than the increase in coal prices, which had an impact on the increase in CPI. Inflationary responses to coal price shocks are sudden in the short run, and the impact tapers off over time. An increase in coal prices can increase inflation, one of which is through an increase in agricultural products. Du et al. (2022) found that their study showed that rising coal prices increased the prices of agricultural products in China. The use of coal in the production, distribution, and storage of agricultural products causes its cost to increase when the price of coal increases.

Naghdi and Kaghazian (2015) obtained empirical findings of an asymmetric long-run relationship between the exchange rate and CPI. An increase in the exchange rate increases the CPI, which means inflation. For countries dependent on imports, the movement of domestic prices will be significantly affected by changes in exchange rates. The impact of a negative exchange rate shock on inflation is more pronounced than a positive shock. Kayamo (2021) states that the real exchange rate has short-run and long-run asymmetric effects on inflation. In the long run, exchange rate imbalances trigger price spikes that lead to high inflation. Exchange rate stability that guarantees price stability is prioritized over exchange rate restrictions to control inflation. Lily et al. (2021) stated that changes in exchange rates have an inflationary impact in the long run and can be asymmetric. The depreciation of the domestic currency drives inflation by increasing the cost of importing goods and services.

El Bejaoui (2013) states that there is an asymmetric effect of the exchange rate on export and import prices. An asymmetric pass-through means that export and import prices respond differently when the local currency depreciates and appreciates. Appreciation of the local currency drives a more pronounced pass-through to export and import prices than when the currency depreciates. Because of that, the exchange rate can asymmetrically affect domestic inflation through cost-push inflation. Inflation rises when import prices increase due to depreciation.

In contrast, inflation falls when import prices decrease due to the local currency's appreciation with unequal effects on changes. Valogo et al. (2023) presented their findings that the depreciation of the home currency boosted inflation significantly when the depreciation exceeded the monthly threshold of 0.71%. Determination of thresholds can provide confidence to assist the monetary authority in controlling inflation by determining the stabilization of the exchange rate at any level that adjusts to the level of policy.

Based on the previous literature review, four hypotheses in this study were proposed related to changes in energy prices and exchange rates.

- H1: Crude oil prices have asymmetric positive effects on CPI inflation
- H2: Natural gas prices have asymmetric positive effects on CPI inflation
- H3: Coal prices have asymmetric positive effects on CPI inflation
- H4: The exchange rates have asymmetric positive effects on CPI inflation

3. METHODOLOGY

Modeling the CPI inflation behavior in this study focuses more on the predictor variables of world energy prices consisting of oil, natural gas, and coal prices, whose use makes up the three largest primary energy sources in Indonesia, plus another predictor, namely the exchange rate, which is also involved in the pass-through into CPI inflation through cost-push inflation. The predictors involved in this inflation model specify energy prices

and exchange rates involved in export-import activities through international markets.

The dependent variable in this model is the CPI expressed in natural logarithms. CPI changes in natural logarithms reflect inflation. CPI data use the base year 2012 (2012=100), processed from raw data obtained from Statistics Indonesia. World crude oil, natural gas, and coal prices are denoted by COP, NGP, and CP, respectively, and expressed in natural logarithms. Meanwhile, the exchange rate is denoted by EXR, measured in rupiah per US dollar, and expressed in natural logarithms. Crude oil prices are measured by the average of Brent, Dubai, and WTI crude oil in $/bbl. Natural gas prices are the average of US, European, and Japanese natural gas in $/mmbtu. Meanwhile, coal is calculated from the average Australian and South African coal in $/mt. An increase in EXR means depreciation of the rupiah, and a decrease in EXR means an appreciation of the rupiah. The superscript "+" and "-" on each independent variable expresses increase and decrease. Data on COP, NGP, and CP were obtained from World Bank Commodity Prices Data, while exchange rates were obtained from Indonesian Economic and Financial Statistics, Bank Indonesia. The data used are monthly for the period 2001M01 to 2022M12.

Changes in energy prices that impact CPI inflation are transmitted through administered inflation, and food inflation is affected by rising oil prices. Inflation in this study assumes CPI inflation which involves administered price inflation, namely inflation which is mainly influenced by fuel subsidized price policies, electricity tariffs, transportation, gas prices, and others which are strongly affected by world energy prices and changes in exchange rates. This inflation also emphasizes the supply side as a source of inflation called cost-push inflation which originates from changes in exchange rates, imported inflation, administered prices due to changes in energy prices, and supply shocks due to natural disasters and distribution chain disruptions.

$$CPI_t = \beta_0 + \beta_1^+ COP^+ + \beta_1^- COP^- + \beta_2^+ NGP^+ + \beta_2^- NGP^- + \beta_3^+ CP^+ + \beta_3^- CP^- + \beta_4^+ EXR^+ + \beta_4^- EXR^- + u_t \quad (1)$$

with the expected parameters including

$$\beta_1^+ > 0, \beta_1^- > 0, \beta_2^+ > 0, \beta_2^- > 0, \beta_3^+ > 0, \beta_3^- > 0, \beta_4^+ > 0, \beta_4^- > 0$$

and $\beta_1^+ \neq \beta_1^-, \neq \beta_2^+ \neq \beta_2^-, \neq \beta_3^+ \neq \beta_3^-, \neq \beta_4^+ \neq \beta_4^-$

The effect of increasing and decreasing explanatory variables is measured by the positive and negative partial sum decompositions of z variables as follows.

$$z_t^+ = \sum_{j=1}^{t} \Delta z_j^+ = \sum_{j=1}^{t} \max\left(\Delta z_j, 0\right) \quad (2)$$

$$z_t^- = \sum_{j=1}^{t} \Delta z_j^- = \sum_{j=1}^{t} \min\left(\Delta z_j, 0\right) \quad (3)$$

The z variables include COP, NGP, CP, and EXR

In this study, the positive and negative partial sum decompositions, generally used in the nonlinear autoregressive distributed lag (NARDL) model developed initially by Shin et al. (2014), are applied in the quantile regression model. This method is an alternative solution when the NARDL model experiences non-normality problems. Even Cho et al. (2023) have developed an estimation of the NARDL model with quantile regression. Also through quantile regression models, asymmetric effects can be captured through the differences in the regression slopes between quantiles. The advantages of the quantile regression model are parameter estimates that are not sensitive to outliers and when faced with non-normality problems (Huang et al., 2017). The quantile regression model for the conditional expected y is expressed as follows.

$$Q = \left(y|Z = z_i; q\right) f\left(\hat{\beta}; z_i\right) \quad (4)$$

Where probability $\left(y \leq f\left(\hat{\beta}; z_i\right)\right) = q$ and

$$z_i = \sum_{i=1}^{n} z_i^+ + \sum_{i=1}^{n} z_i^- \quad (5)$$

The dynamic OLS model is applied in this study to estimate long-run parameters in equation (1). Using the dynamic OLS model as an alternative model with a parametric approach considers the problems of serial correlation and endogeneity as well as bias in small samples (Ullah et al., 2020). The dynamic OLS model involves lag and lead regressors.

4. RESULTS

The statistical summary in Table 1 provides a statistical description of the consumer price index, world prices of crude oil, natural gas, and coal, and exchange rates. The CPI has a minimum value of 41.64 which is the CPI at the beginning of the period, and the maximum value is 152.06, which is the CPI at the end of the period with the 2012 base year. Changes in the CPI in Indonesia are very dynamic, experiencing declines along the increasing trend of the CPI all the time. This dynamic change in CPI results in inflation that fluctuates with changes in world energy prices, especially world crude oil prices. However, from the summary statistics, the CPI has the smallest absolute skewness value among the variables analyzed. The small skewness value is because the CPI has an average value close to the median. The median of the CPI was 97.52 at the beginning of 2012 from January 2001 to December 2022.

World crude oil prices tend to fluctuate throughout the study period. The lowest price of 18.52 $/bbl, the minimum oil price in summary statistics, is the price of world crude oil in December 2001, not at the beginning of the period. Meanwhile, the highest oil price of 132.83 $/bbl, the maximum in this period, was the oil price in July 2008, and not at the end of the period. The highest oil price that occurred in 2008 indicates that the movement of world crude oil prices tends to fluctuate. Because of this, world crude oil prices have greater skewness than the CPI, with the mean value slightly deviating from the median.

The lowest natural gas price of 3.15 $/mmbtu as a minimum price during the study period occurred in February 2002 and not at the beginning. Meanwhile, the highest natural gas price of 33.35 $/

Table 1: Summary statistics

Variable	Mean	Median	Min	Max	SD	Skewness	Kurtosis
CPI	98.0349	97.5200	41.6400	152.0600	33.1537	−0.0908	1.6884
COP	65.2448	61.6600	18.5200	132.8300	27.6470	0.2680	2.0866
NGP	7.9125	7.1100	3.1500	33.3500	4.1087	2.5936	13.0648
CP	83.0983	71.6650	21.7500	340.7900	56.3794	2.6802	11.6187
EXR	11,247.20	10,232.50	8,279.00	16,367.00	2,313.96	0.3819	1.5255

Note: CPI in index with 2012=100, COP in $/bbl, NGP in $/mmbtu, CP in $/mt, and EXR in Rp/$

mmbtu as the maximum price during the analysis period occurred not at the end but in August 2022. World natural gas prices also tend to fluctuate similarly to world oil prices but with price spikes in 2021-2022. The value distribution of natural gas prices has a reasonably large skewness value, which means that the value distribution of natural gas prices tends to be skewed.

World coal prices fluctuate the most among the three types of energy prices. Throughout the study period, the lowest coal price of 21.75 $/mt occurred in August 2002, and the highest price of 340.79 $/mt occurred in August 2022, similar to when the highest price of natural gas occurred. However, the spike in coal prices in 2022 is very high, which illustrates the high fluctuations in coal prices. The deviation of the mean to the median causes the value distribution of coal prices to be skewed, similar to the skewness of the value distribution of natural gas prices.

The exchange rate during the study period varied, with the lowest value of 8.279 rupiahs per US dollar in May 2003 and the highest value of 16.367 rupiahs per US dollar in March 2020, when the Covid-19 pandemic occurred in Indonesia. Along with implementing a free-floating exchange rate system, the exchange rate measured in rupiah per US dollar fluctuates but tends to increase in the long run. This increase in value indicates that the rupiah will experience depreciation in the long run.

Table 2 presents the results of the unit root tests from the data series of the variables in the analyzed model. With the ADF test with constant, and with constant and trend, it was found that all variables were stationary at the first difference or I(1). The variables in the model with characteristics I(1) allow estimation models with quantile regression and dynamic OLS to be carried out.

Table 3 reports that world crude oil prices have an asymmetric effect on inflation between increases and decreases in oil prices. Increases and decreases in world crude oil prices significantly impact inflation with a P-value of 0.01. The increase in oil prices increases the CPI, which means inflation occurs. Conversely, decreasing oil prices lowers the CPI, meaning there is deflation or negative inflation. The dynamic OLS model and quantile regression show similar results in that the decline in world crude oil prices has a more significant impact than price increases on inflation.

In addition to changes in world crude oil prices, based on dynamic OLS estimation, inflation has also been affected by the decline in global coal prices. The decline in coal prices significantly lowered the CPI with a P-value of 0.05, meaning deflation. However, judging from the regression coefficient, the effect of the increase in coal prices is lower than the increase in crude oil prices. This result means that the decline in the CPI was contributed more by the decline in crude oil prices. Meanwhile, for rising inflation, rising world crude oil prices dominated the impact on driving domestic inflation.

Table 2: Unit root tests

Series	ADF test with constant		ADF test with constant and trend	
	Level	First Difference	Level	First Difference
LCPI	−3.9662***	−10.6035***	−1.3263	−11.5038***
$LCOP^+$	0.1958	−6.6676***	−1.4347	−6.6564***
$LCOP^-$	0.6630	−9.7047***	−2.1747	−9.7493***
$LNGP^+$	0.7501	−3.1796**	−1.9216	−3.3376*
$LNGP^-$	1.4020	−8.5780***	−1.2679	−8.6944***
LCP^+	0.6063	−4.2573***	−2.1580	−4.3473***
LCP^-	0.4511	−12.6811***	−3.1909*	−12.6881***
$LEXR^+$	−1.0846	−12.493***	−3.3908*	−12.509***
$LEXR^-$	−1.6727	−7.7625***	−1.9207	−7.8181***

***P-value <0.01, **P-value <0.05, *P-value <0.1

Table 3: Regression results of the dynamic OLS and quantile regression (median), dependent variable: LCPI

Variables	Dynamic OLS		Quantile regression (median)	
	Coefficient	Standard Error	Coefficient	Standard Error
C	3.6016***	0.0354	3.6230***	0.0200
$LCOP^+$	0.1249***	0.0325	0.0709***	0.0257
$LCOP^-$	0.1465***	0.0375	0.1523***	0.0263
$LNGP^+$	−0.0066	0.0320	−0.0083	0.0154
$LNGP^-$	−0.0112	0.0530	0.0292	0.0377
LCP^+	−0.0276	0.0248	0.0022	0.0211
LCP^-	0.0933**	0.0385	0.0264	0.0390
$LEXR^+$	0.6218***	0.0611	0.6580***	0.0533
$LEXR^-$	−0.1857***	0.0711	−0.1911***	0.0364

***P-value <0.01, **P-value <0.05

Exchange rate changes also contributed to inflation in Indonesia. An increase in the rupiah exchange rate per USD, which means there is a depreciation of the rupiah, significantly increases domestic inflation with a P-value of 0.01. Judging from the regression coefficient, the effect of the rupiah depreciation is greater than the increase in crude oil prices. The depreciation of the rupiah caused the price of imported crude oil and fuel to be more expensive, thus pushing up inflation with a higher CPI increase. The asymmetric effect of changes in the exchange rate is evident when the rupiah appreciates, but inflation still occurs. The decline in the rupiah exchange rate per USD, which means that there is an appreciation of the rupiah, continues to increase the CPI, which means that inflation will continue.

From Table 4, it can be revealed that through the Wald t-test, there is a significant asymmetric effect in world crude oil prices with differences in the parameter value for increases and decreases in oil prices on consumer prices, as presented in Table 3 in the quantile regression model. Meanwhile, there is no evidence of an asymmetric effect of changes in natural gas and coal prices on consumer prices. There is an exchange rate asymmetric effect between when the rupiah depreciates and appreciates against the CPI. The results of the Wald t-test reject the null hypothesis for the estimated parameter of the dynamic OLS and quantile regression models, which means that exchange rates have a significant asymmetric effect on consumer prices. So according to these findings, there is evidence of an asymmetric pass-through of the exchange rate into consumer prices.

Tables 5 and 6 report that the estimation of the quantile regression model shows a significant positive effect, but asymmetrically, between price increases and decreases in world crude oil prices on the CPI and is evident in the middle and upper quantiles. Separately, the positive effect of rising world oil prices on the CPI is only evident in the regression of the top five quantiles. Meanwhile, the significant positive effect of the decline in oil prices on consumer prices was evident in all quantiles.

For natural gas prices, with P-values of 0.05 and 0.1, a significant positive effect was found in the upper quantile regression results, i.e., in the seventh and eighth quantiles. The decline in world natural gas prices can be followed by a decrease in consumer prices, which means deflation. Meanwhile, the regression results for all quantiles found no evidence of a significant effect of world coal prices on domestic consumer prices.

Table 4: Test for asymmetric effects of the dynamic OLS and quantile regression (median) model

Variables	Ho	Wald t-statistic	
		Dynamic OLS	Quantile regression (median)
LCOP	$\beta_1^+ = \beta_1^-$	−0.5731	−2.5986***
LNGP	$\beta_2^+ = \beta_2^-$	0.0948	−1.0564
LCP	$\beta_3^+ = \beta_3^-$	−2.5641**	−0.5640
LEXR	$\beta_4^+ = \beta_4^-$	10.1969***	16.0534***

***P-value <0.01, **P-value <0.05

The regression results for all quantiles confirm that the exchange rate has a significant asymmetric effect with the difference between positive and negative effects on consumer prices. A significant positive effect is evident when the rupiah depreciates, and a significant negative effect is evident when the rupiah appreciates influencing consumer prices. Changes in the exchange rate, up and down, increased the consumer price index. So, exchange rate changes are inflationary in the long run.

In addition to the asymmetric effect between the increase and decrease in energy prices, an asymmetric effect between quantiles is also found through quantile regression. Table 7 presents the results of the equality test of the estimated parameters for the variables in the model. The estimated parameters for increases in world oil prices have an asymmetric effect between the third and fifth quantiles and the fourth and fifth quantiles. These results prove that increases in world oil prices have different positive effects on consumer prices at different CPI levels. Meanwhile, the decline in world oil prices only had a positive effect that differed between the first and fifth quantiles using a p-value test of 0.1. So, the positive effects at different CPI levels are more pronounced in increases than decreases in world oil prices.

The positive effect of the rupiah's depreciation on consumer prices was the difference between the lower and middle quantiles, represented by the fifth quantile. So, the positive effect of the exchange rate has various pass-throughs at different CPI levels. Likewise, the negative effect of rupiah appreciation also occurs at differences between CPI levels.

Tables 8 and 9 presented short-run parameter estimates of changes in energy prices and the exchange rate against the CPI. In the short run, there is little evidence of the influence of energy prices and the exchange rate on the CPI. The effect of changes in energy prices and exchange rates has a different pattern of long-run estimates. The increase in world oil prices significantly lowered CPI in the short run, found in the seventh quantile with a P-value of 0.1.

The decline in natural gas prices significantly lowered the CPI found in the third, fourth, sixth, eighth, and ninth quantiles. Meanwhile, coal prices increased consumer prices in the fourth quantile. A decrease in coal prices increased the CPI in the lower quantiles, conversely lowering the CPI in the upper quantiles. For the exchange rate, short-run effects are only found in rupiah appreciation, with different effects between the fourth quantile

Table 5: Regression results of the quantile regression (lower and middle quantiles)

Variables	Lower quantiles			Middle quantiles		
	$Q_{0.1}$	$Q_{0.2}$	$Q_{0.3}$	$Q_{0.4}$	$Q_{0.5}$	$Q_{0.6}$
C	3.6280***	3.6337***	3.6007***	3.6227***	3.6230***	3.6217***
$LCOP^+$	0.0403	0.0302	−0.0020	−0.0109	0.0709***	0.0829***
$LCOP^-$	0.0810**	0.1100**	0.1072**	0.1388***	0.1523***	0.1638***
$LNGP^+$	−0.0378	−0.0552	−0.0286	−0.0171	−0.0083	−0.0042
$LNGP^-$	0.0909	0.0493	0.0433	0.0158	0.0292	0.0289
LCP^+	0.0319	0.0535	0.0438	0.0345	0.0022	−0.0085
LCP^-	−0.0410	−0.0422	−0.0080	−0.0557	0.0263	0.0250
$LEXR^+$	0.3255***	0.4088***	0.5303***	0.5310***	0.6580***	0.6794***
$LEXR^-$	−0.3939***	−0.3171***	−0.3402***	−0.3006***	−0.1911***	−0.1795***

***P-value <0.01, **P-value <0.05

(middle quantile) and the eighth and ninth quantile (upper quantile). In the fourth quantile, the rupiah appreciation pushed down consumer prices. Conversely, the rupiah's appreciation boosted the CPI in the eighth and ninth quantiles.

5. DISCUSSION

The results of this study provide empirical evidence that there are asymmetrical effects on the movement of world energy prices, especially crude oil, when they rise and fall on CPI inflation in Indonesia. The finding of an asymmetrically positive effect of oil prices on inflation confirms the results of research by Donayre and Wilmot (2016), Bala and Chin (2018), Sek (2019), Bawa et al. (2020), Babuga and Naseem (2021), Ayisi (2021), Sarmah and Bal (2021), and Nie (2023). Specifically, however, these findings differ from those by Babuga and Naseem (2021) and Nie (2023), that increases in oil prices have a more significant effect on inflation than decreases. From the results of this study, the decline in world crude oil prices had a more significant effect in reducing the CPI than the increase in oil prices, which had the effect of increasing the CPI. These results confirm the results of a study by Donayre and Wilmot (2016) in Canada and a study by Bala and Chin (2018) in countries that implement food and fuel price subsidy policies. The government's fuel price subsidy policies, when the world crude oil price increases, can reduce the rate of increase in general prices.

The results of this study clarify the previous study by Artami and Hara (2018), which stated that there was no significant effect of increases and decreases in oil prices on inflation in Indonesia during the period 1990Q1-2016Q4 due to the implementation of oil price subsidies. So, with the period of this study, which began after the 1997-1998 economic crisis, this study provides more evident results that subsidies may reduce the effect of rising oil prices on inflation rather than decreasing oil prices with a significant effect of rising and falling oil prices on CPI inflation. The fuel price subsidies are a necessity for people's lives because Indonesia is a country that imports crude oil and fuel. The limited availability of oil refineries is the leading cause of dependence on oil imports, even though Indonesia produces crude oil. Meanwhile, inflation is the main focus of monetary policy, and it is seen that non-monetary factors such as world oil prices are the main contributor to inflation through administered inflation. However, increases in world oil prices tend to be wary of giving the potential to push up inflation. The effect of rising oil prices on rising CPI in this study is confirmed by the findings of Syzdykova et al. (2022) for the case of India.

The effect of changes in natural gas prices on inflation is relatively small compared to the effects of changes in oil prices. The study by Jalaee et al. (2021) also stated that changes in natural gas prices have a relatively low impact.

This study also found evidence that the decline in coal prices significantly lowered the CPI, and it was proven that there was an asymmetry effect through the estimation of the dynamic OLS model. The finding of the effect of coal prices on CPI inflation in this study is supported by the findings of Guo et al. (2016), that the decline in coal prices significantly reduced CPI, and there was an asymmetric effect. Chen (2014) suggests that changes in CPI

Table 6: Regression results of the quantile regression (upper quantiles)

Variables	Upper quantiles		
	$Q_{0.7}$	$Q_{0.8}$	$Q_{0.9}$
C	3.6468***	3.6880***	3.7115***
$LCOP^+$	0.0955***	0.1013***	0.0386
$LCOP^-$	0.1522***	0.1273***	0.0856*
$LNGP^+$	0.0094	0.0032	0.0704
$LNGP^-$	0.0532*	0.0733**	0.0533
LCP^+	−0.0203	−0.0208	−0.0087
LCP^-	0.0216	0.0162	0.0439
$LEXR^+$	0.6830***	0.6335***	0.5489***
$LEXR^-$	−0.1353***	−0.1219**	−0.1526

***P-value <0.01, **P-value <0.05, *P-value <0.1

Table 7: Asymmetric model of the quantile regression model (based on restriction value)

Ho	$\beta_{Q0.1}=\beta_{Q0.5}$	$\beta_{Q0.2}=\beta_{Q0.5}$	$\beta_{Q0.3}=\beta_{Q0.5}$	$\beta_{Q0.4}=\beta_{Q0.5}$
$LCOP^+$	−0.0305	−0.0407	−0.0729***	−0.0818***
$LCOP^-$	−0.0713*	−0.0423	−0.0450	−0.0134
$LNGP^+$	−0.0295	−0.0468	−0.0203	−0.0087
$LNGP^-$	0.0617	0.0201	0.0141	−0.0134
LCP^+	0.0297	0.0513	0.0416	0.0323
LCP^-	−0.0674	−0.0686	−0.0344	−0.0820***
$LEXR^+$	−0.3325***	−0.2492**	−0.1277*	−0.1270***
$LEXR^-$	−0.2028**	−0.1260	−0.1491**	−0.1095***

***P-value <0.01, **P-value <0.05, *P-value <0.1

Table 8: Regression results for the short run of the quantile regression model (lower and middle quantiles), dependent variable: ΔLCPI

Variables	Lower quantiles			Middle quantiles		
	$Q_{0.1}$	$Q_{0.2}$	$Q_{0.3}$	$Q_{0.4}$	$Q_{0.5}$	$Q_{0.6}$
C	0.0000	0.0007	0.0020***	0.0029***	0.0037***	0.0055***
$\Delta LCOP^+$	−0.0135	0.0007	−0.0029	−0.0041	−0.0013	−0.0050
$\Delta LCOP^-$	−0.0012	−0.0021	0.0015	−0.0058	−0.0036	−0.0041
$\Delta LNGP^+$	−0.0082	−0.0060	−0.0091	−0.0042	−0.0096	0.0002
$\Delta LNGP^-$	0.0052	0.0081	0.0111*	0.0132**	0.0086	0.0148**
ΔLCP^+	0.0123	0.0075	0.0065	0.0120*	0.0087	0.0044
ΔLCP^-	−0.0096**	−0.0080*	−0.0044	−0.0024	0.0028	0.0052
$\Delta LEXR^+$	−0.0034	−0.0096	−0.0045	−0.0056	0.0142	−0.0011
$\Delta LEXR^-$	0.0197	0.0187	0.0243	0.0409*	0.0327	0.0298
u_{t-1}	−0.0047	−0.0039	−0.0023	−0.0005	−0.0167	−0.0067

***P-value <0.01, **P-value <0.05, *P-value <0.1

Table 9: Regression results of the short run of the quantile regression model (upper quantiles), dependent variable: ΔLCPI

Variables	Upper quantiles		
	$Q_{0.7}$	$Q_{0.8}$	$Q_{0.9}$
C	0.0072***	0.0082***	0.0113***
$\Delta LCOP^{+}$	−0.0148*	−0.0117	0.0051
$\Delta LCOP^{-}$	0.0005	−0.0089	−0.0088
$\Delta LNGP^{+}$	−0.0042	−0.0163	−0.0314***
$\Delta LNGP^{-}$	0.0139	0.0199**	0.0389***
ΔLCP^{+}	−0.0015	0.0057	−0.0055
ΔLCP^{-}	0.0099*	0.0185***	0.0092
$\Delta LEXR^{+}$	0.0057	0.0096	−0.0314
$\Delta LEXR^{-}$	−0.0141	−0.0699***	−0.0628***
u_{t-1}	−0.0071	−0.0290	−0.0256*

***P-value <0.01, **P-value <0.05, *P-value <0.1

are associated with increased coal prices. However, the increase in coal prices did not significantly increase CPI inflation. This result is in line with the findings of Song and Wang (2016) that there is no evidence that rising coal prices encourage inflation through cost push.

The change in the exchange rate in this study also makes a significant contribution to CPI inflation. Inflation occurs when the rupiah appreciates and depreciates so that there is an asymmetry effect of the exchange rate on inflation. The results of this study support the empirical findings by Kayamo (2021) that inflation has an asymmetric effect on inflation, with the depreciating effect of the exchange rate being more inflationary than appreciation. As an empirical finding in Thailand, the study by Lily et al. (2021) also confirms that inflation occurs when the local currency appreciates. The reduction in import costs did not affect consumer prices.

The asymmetric effect in the empirical findings also indicates the presence of unequal estimated parameters between quantiles. These results indicate that the increase in world oil prices and the rupiah's appreciation in influencing CPI inflation provide different estimated parameters between the upper and middle quantiles. This result means that the increase in oil prices and the rupiah depreciation have different power of influence between CPI levels, with a more decisive influence on the middle quantile regression results. At a higher CPI level, the effect of rising oil prices and the appreciation of the rupiah is getting stronger.

In estimating the effect of the short run, there is sufficient evidence regarding the effect of reduced natural gas prices on CPI inflation in the upper and middle quantiles. There is little evidence that increases in coal prices cause inflation in the regression of the fourth quantile. Meanwhile, there is no evidence of the effect of changes in the exchange rate on changes in the CPI in the short run. Empirical studies related to the asymmetric effect of world oil prices on inflation only found evidence for long-run effects but not for short-run effects, in line with findings by Ayisi (2021). In general, the behavior of changes in energy prices and exchange rates tends to fluctuate so that it does not affect inflation according to theoretical expectations. Overall, world energy prices that have the most positive effect on CPI inflation are changes in oil prices when they rise and fall and the depreciation of the rupiah.

6. CONCLUSION AND POLICY IMPLICATION

The decline in world crude oil prices positively affected the decline in the CPI, with a more considerable effect than the increase in oil prices, which pushed up the CPI. When the government carried out the oil price hike, the fuel price subsidy policy reduced the increase in general prices. Little empirical evidence was found in this study for the long-run effect of lower coal prices lowering CPI. In addition, the short-run effect of a decrease in natural gas prices affects a decrease in CPI and an increase in coal prices on an increase in CPI.

These empirical findings provide additional insight that the source of domestic inflation is internal macroeconomic factors and external factors such as changes in world prices of crude oil, natural gas, and coal, which have become sources of inflation due to Indonesia as an oil importing country. The exchange rate is also another major factor as a source of inflation in Indonesia. Through cost-push inflation, exchange rate changes are passed on to domestic inflation.

The results of this study imply that controlling inflation can be assisted by efforts to control the impact of energy price shocks, especially oil price shocks, by improving the infrastructure and facilities that support the production and distribution of fuel, including the development of oil refineries. These efforts can reduce dependence on oil imports, while Indonesia can also produce crude oil, reducing the impact of world oil price fluctuations on domestic inflation. Finally, from a monetary policy standpoint, controlling the exchange rate so that stability is maintained will help control inflation, especially inflation originating from supply shocks.

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