do oil price fluctuation affect the inflation rate in Indonesia asymmetrically?

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DO OIL PRICE FLUCTUATIONS AFFECT THE INFLATION RATE IN INDONESIA ASYMMETRICALLY?

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Changes in the oil price directly affect production costs, and subsequently, the general price level of products. With Indonesia observing an inflation targeting policy, this study applies the nonlinear autoregressive distributed lag (NARDL) technique to investigate the effect of oil price fluctuations in Indonesia. The relationship is important for the central bank to gauge the effectiveness of the inflation targeting policy in immunizing the country from oil price fluctuations. Our findings have revealed that there was an asymmetric behavior between oil price and the inflation rate (producer price index), thus questioning the effectiveness of the inflation targeting policy. More specifically, in the long run, an increase in the oil price will tend to lead to an increase in the rate of inflation with a greater deviation, while an oil price reduction will lead to a decrease in the inflation rate with a lower deviation. This suggests that the benefits of an oil price reduction are not passed down to the consumer.

Keywords: Inflation targeting; oil price; asymmetric cointegration; Indonesia.

JEL Classification: D4, H5, Q4.

1. Introduction

Indonesia has been observing a policy of inflation targeting since 2005, with the latest target being set at 3.5% ± 1% for the year 2019. The terminology of inflation targeting is

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often misinterpreted by normal citizens, where they often assume that the country's inflation rate is stagnating at 3.5–4.5% or even that there is a zero rate of inflation. However, the inflation rate is progressively compounding; for instance, a policy of targeting inflation at 3.5% indicates that the general price level is expected to increase by not more than 3.5%, compared to the last year. For example, the consumer price index (CPI) in Indonesia, as recorded in the third quarter (Q3) of 2019, stood at 150.3 which was approximately 50 index points higher than the level of CPI recorded in Q3 of 2010 (101.30), and approximately 20% more than the level of CPI recorded in Q3 of 2015 (133.54) (IMF, 2019). In short, the general price level is always increasing in Indonesia. What worries the citizens is that whether their income can catch up with the rate of inflation or the inflation targeting policy rate, *per se*?

Fluctuations in the oil price will directly affect product prices, or production costs, and subsequently, the general price level. Therefore, it is not surprising that the instability of oil prices in recent years has stimulated many types of academic research and interested discussions on the implications of oil price changes upon the rate of inflation. Indonesia's crude oil production has been experiencing a steady downward trend since 1990, which, in combination with increased domestic demand, has turned Indonesia into a net oil importer since 2004. Indonesia's crude oil imports in 2016 and 2017 were reported at USD 6730.60 million and USD 7063.60 million, respectively. Bank Indonesia, the central bank of Indonesia, reported that, as of December 2018, the value of oil and gas exports for 2018 amounted to USD 1.3 billion, while imports amounted to USD 3 billion. With Indonesia being heavily reliant on oil imports to satisfy the local demand, a soaring oil price is, therefore, expected to exert positive pressure on the inflation level of the country.

Very often, the effects of higher oil prices are passed on to the end users, either directly through increments in product prices (petroleum products) or indirectly through increased transportation costs or unit production costs. However, in the case of an oil price reduction, businesses are either quite reluctant to reduce prices or the percentage of adjustment is significantly lower, due to profiteering. As a result, the relationship between inflation rate and the oil price is not symmetrical in practice. Therefore, what is the actual impact of oil price fluctuations on the general price levels in Indonesia? Will the magnitude of impact on the inflation rate be greater when oil prices increase rather than when they reduce?

Indonesia is the fourth most populated country in the world with a population of 267 million people and a relatively high poverty level — approximately 10.9% — recorded in the year 2016 (World Bank, 2017). It is, therefore, important for policymakers to ensure price stability. Hence, unsurprisingly, the Indonesian government, together with Bank Indonesia, the central bank of Indonesia, established a coordination mechanism to keep the inflation rate of Indonesia between 2.5% and 4.5%, this policy came into effect in 2005. As the oil price can affect the general price level, both directly and indirectly, thus, the general price level is very vulnerable to fuel price fluctuations. Therefore, a study on the asymmetric integration of the inflation–oil price nexus is needed.

Historically, the inflation rate of Indonesia has been fluctuating in the positive zone since 1970, and was at its peak, at a growth rate of 58.9%, during the Asian Financial Crisis throughout 1998–1999. With the country's energy prices being determined by the government, rather than based on market conditions, the Indonesian government has spent trillions of Indonesian rupiahs on fuel subsidies. For example, the Indonesian government spent approximately 246.5 trillion Indonesian rupiahs in 2014 on fuel subsidies, whilst it only spent approximately 47 trillion Indonesian rupiahs in 2017, as a result of the government's decision to cut fuel subsidies in late 2014. The cut in fuel subsidies pushed Indonesia's monthly inflation rate to 1.50% and 2.46% during November and December 2014, respectively. As reported by Reuters (2019), in 2018 the Indonesian government spent 153.5 trillion Indonesian rupiahs on energy subsidies. Three observations can be drawn from Indonesia's fuel subsidy policy. First, Indonesia relies heavily on fuel subsidies. Second, the general price level is rather sensitive to oil price fluctuations. Third, fuel subsidies could not prevent the inflation rate from continuing to soar. Hence, increments in the general price level could be due to increments in the producer price index (PI) due to the impact of oil price fluctuations, as captured through higher import costs (transportation costs) and imported input prices.

This study contributes to the existing literature in four important aspects. First, we adopted the nonlinear autoregressive distributed lag (NARDL) model, proposed by Shin *et al.* (2014), to highlight the potential long-run asymmetries in the inflation–oil price nexus. Second, this study examined the immunization of the inflation targeting policy from oil price fluctuations. Third, given that Indonesia has turned into a net oil importer since the early 2000s, this study may prompt the policymakers to explore alternative energy resources, instead of relying heavily on crude oil. Considering that crude oil is a nonrenewable resource, the Indonesian government may be required to hike their fuel price subsidies in the future to ensure price stability. Fourth, this study investigated the pass-through effects of the oil price on producer prices in Indonesia.

The remainder of this paper is structured as follows. Section 2 provides the background of the study, which is followed by a review of the previous literature. Section 3 outlines the methodology and data. Section 4 reports and discusses the empirical results. Finally, Section 5 offers both policy implications and concluding remarks.

2. Theoretical Background

The theoretical background of the impact of oil price fluctuations on producer prices in this study can be explained based on the calculation of the Gross Domestic Product (GDP), using the production approach (value-added). The mathematic representation of the production approach is as follows:

$$\mathrm{GDP} = P_1Q_1 + P_2Q_2 + P_3Q_3 + P_4Q_4 + \cdots + P_nQ_n. \quad (1)$$

Equation (1) highlights the GDP that measures the market value of all final goods and services produced within a country, in a given time. As postulated by the production approach, only the total value added at all of the stages of production is accounted in the GDP, hence, mathematically, the total is equal to the value of the final output $(P_1Q_1 + P_2Q_2 + P_3Q_3 + P_4Q_4 + \cdots + P_nQ_n)$, as long as the value chain goes back to the first stage of production.

The impact of oil price fluctuations on producer prices (product price) can be explained based on the production flowchart presented in Figure 1. As indicated in Figure 1, oil price fluctuations will have an impact on producer prices in various ways: first, as a direct consequence, if the input or raw material is an oil-based product; second, as an indirect influence, through oil-based processes and transportation cost fluctuations. Hence, oil price fluctuations are expected to lead to the variation of producer prices, both directly or indirectly.

2.1. *Literature review*

2.1.1. *Empirical evidence on the asymmetric cointegration of oil price and inflation*

Our argument on the asymmetric relationship between oil price fluctuations and inflation is derived from the concept of sticky prices (price stickiness hypothesis) instituted by Rotemberg (1983). As postulated by the hypothesis, price changes are costly, hence prices do not reach a long-run value instantly after an oil shock. The author also concluded that, in the United States, although increments in the energy prices ultimately lead to higher domestic prices, the response is not immediate. The stickiness of prices was due to the

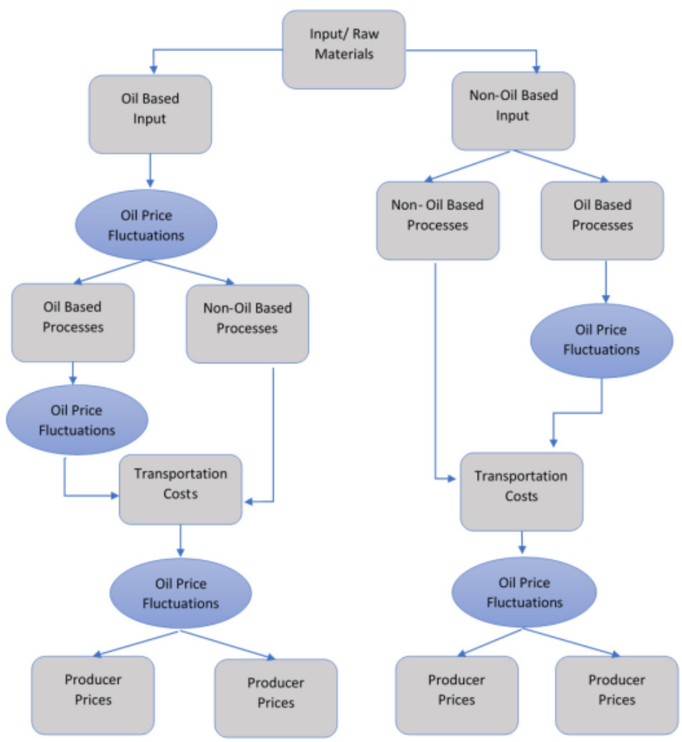

Figure 1. Production Flows Highlighting the Impact of Oil Price Fluctuations on Producer Prices

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presence of costs associated with changing prices. Besides, a few empirical studies have been found to be in parallel with the theoretical argument, where the relationship between oil price fluctuations and inflation was determined to be asymmetric. Those studies included Alimi *et al.* (2020) who explored the asymmetric oil price–inflation nexus of Nigeria using the quarterly data from the year 2009 until 2018 and confirmed the nonlinear long-run cointegration of oil prices and inflation in Nigeria. More specifically, both increments and decrements in global oil prices tended to exert a negative impact on the inflation rate of Nigeria.

Additionally, Salisu *et al.* (2017) investigated the role of asymmetries in the oil price–inflation nexus of net oil-exporting and net oil-importing countries. Their findings revealed that although the oil price and the rate of inflation were positively and significantly correlated in the long run, oil price asymmetries were not detected by the net oil-importing nations. Lacheheb and Sirag (2019) utilized the NARDL method to examine the relationship between oil price fluctuations and the rate of inflation in Algeria based on the data ranging from 1970 to 2014. They confirmed the existence of a nonlinear effect of oil prices on the inflation rate, where oil price increments tended to lead to increased inflation, but oil price reductions did not have an impact on the rate of inflation in Algeria. Similarly, Long and Liang (2018) utilized the NARDL method on the quarterly data from China from the year 1998 and concluded that the impact of global oil price fluctuations on China's PI and CPI was asymmetrical in the long run. More specifically, the impact of upward oil price fluctuations on its PI and CPI was greater than that of oil price reductions.

Further evidence was provided by Sek (2017), who detected both symmetric and asymmetric pass-through effects from the oil price on the domestic prices in Malaysia, where the direct impact of oil price fluctuations on the domestic prices, in the long run, was concentrated on oil-intensive sectors, rather than on the general price level. In evaluating the impact of global oil price fluctuations on the domestic inflation level in 72 advanced and developing economies, over the period from 1970 to 2015, Choi *et al.* (2017) found that the effect of fluctuations of the oil price on the inflation rate was asymmetric, where the impact of positive oil price fluctuations was larger than that of oil price reductions. Hammoudeh and Reboredo (2018) using a Gaussian affine term structure model, on the data from the United States, concluded that oil prices had a nonlinear impact on the 5- and 10-year market-based inflation expectation components. Specifically, they found that the impact of oil price changes on inflation expectations was more intense when the oil prices were above a threshold of US$67 per barrel and were more pervasive for the intermediate term than for the long term.

On the other hand, the majority of works in the existing literature have claimed that the relationship between oil price fluctuations and inflation is symmetric, where the percentage change in inflation is identical from either an oil price increase or reduction. Among them, Sek *et al.* (2015) examined the effects of oil price changes on the inflation rate in two groups of countries, on the data ranging from 1980 to 2010, using the autoregressive distributed lag (ARDL) technique. Their study revealed that oil price changes had a direct impact on the domestic inflation rate in a group of low oil dependency countries, however, the impact on the domestic inflation rate of the group of high oil dependency countries was via the changes in exporter's production costs. Dedeoglu and Kaya (2014), using the recursive vector autoregressive (VAR) model, found evidence of an increasing trend in the pass-through effects of oil price fluctuations on the domestic prices in Turkey. The most recent empirical evidence was from Zivkov *et al.* (2019) and concerned the impact of oil price fluctuations on the inflation rates of Central and Eastern European countries. The results suggested that the transmission of fluctuations in the oil price to the rate of inflation caused relatively low effects in both Central and Eastern European countries. However, the strongest impact was found over longer time horizons, which indicated that the indirect spillover effects of oil price fluctuations were more intensive.

Other than that, although most of the existing studies have demonstrated that the oil price and the inflation rate were significantly correlated, the results of their findings have not been unanimous. For example, Myers *et al.* (2017) found that the oil price is cointegrated with the inflation rate in the long run, however, the significance of the long-run cointegration will be conditioned by permanent fluctuations in the oil prices. Castro and Jiménez-Rodríguez (2017) employed a constrained VAR model which indicated that oil price fluctuations were significantly cointegrated with the producer price index in high oil consumption sectors but were not statistically cointegrated with the consumer price index. Similarly, Cunado *et al.* (2015) employed a VAR model which suggested that prices responded differently to oil price shocks. Particularly, they noted that prices responded more significantly to oil price demand shocks rather than to oil price supply shocks.

The above discussions offer some insightful information on the impact of oil price on the rate of inflation, in their respective studies. Although various estimation methods were applied in previous studies to explore the impact of oil price on the economic indicators, there is still a debate as to what extent a country's inflation rate is explained by the oil price. Besides, there is no single study which has examined the asymmetric link between the oil price and inflation in Indonesia, a country with an inflation targeting policy. Hence, this study intends to fill the gap in the literature by exploring the asymmetric impact of oil price on the rate of inflation of Indonesia. Furthermore, most previous studies have focused on the CPI, as a proxy for inflation. We argue that CPI refers to the changes in the price level of a weighted average market basket of consumer goods and services purchased by the households. Hence, for a country with an inflation targeting strategy, most of the goods that are placed in the basket are subjected to price controls or subsidies, hence it often does not reflect the true market value of the goods. Thus, this study explores to what extent oil price fluctuations affect the producer price index of Indonesia.

3. Methodology

3.1. *Asymmetric framework*

Based on the theoretical presentation in Figure 1, we argue that the asymmetric relationship between oil price fluctuations and domestic prices can be observed from two separate models — namely, *The Model in the Absence of Costs of Changing Prices* and *The Model in the Presence of Costs of Changing Prices*, as recommended by Rotemberg (1982, 1983). Both models explain the stickiness of prices which supports the foundation of the asymmetric adjustment in oil price–inflation nexus. Due to the stickiness of prices, price adjustments due to oil price increments and reductions would not be symmetric. The hypotheses of the models are as follows.

3.1.1. *Model in the absence of cost changing prices*

In this model, Rotemberg (1983) assumed that there was no extra cost involved in changing prices. The model consents the oil price (energy) to be both an intermediate and final good:

$$Q_{it} = A_{it}\left(\frac{P_{it}}{D_t}\right)^{-b_i}\left(\frac{M_t}{P_t}\right)^{f}\left(\frac{R_t}{P_t}\right)^{k}, \quad i = 1, 2, \ldots, n, \tag{2}$$

where Q_{it} represents the quantity demanded of good i at time t. P_{it} is the price of good i at time t. M_t refers to the level of money balance, R_t is the price of a commodity (oil price, in this study) whose price is exogenous and D_t is the level of domestic prices. A_{it}, b_i, f and k are parameters.

Accordingly, fluctuations in the oil price would change the quantity demanded of the good, or promote or discourage the demand for substitute goods, in response to the distribution effects of fluctuations in the oil price. The domestic price (D_t), the price level of the good itself (P_t) and the production function (Q_{it}) are as follows:

$$D_t = \left(\prod_{i=1}^{n} P_{it}\right)^{\frac{1}{n}}, \tag{3}$$

$$P_t = D_i^{\mu} R_t^{1-\mu}, \tag{4}$$

$$Q_{it} = H_t N_{it}^{g} E_{it}^{h}, \tag{5}$$

where $0 < \mu_t < 1$, N_{it} is the amount of labor and E_{it} is the amount of energy (oil price) employed by a firm i at time t and the supply of labor is subject to the real wage function:

$$N_{it} = A\left(\frac{W_t}{P_t}\right)^{\lambda}. \tag{6}$$

Solving Equation (6) and the demand for labor implied by Equations (2) and (5). Then each firm would choose the elasticity of demand that is equal to marginal cost,

$$p_{it}^{*} = d_t + s_t + \psi_t(r_t - p_t) + \xi_t(m_t - p_t) \tag{7}$$

subject to

$$\psi(r_t - p_t) + \xi(m_t - p_t) + S = 0. \tag{8}$$

Equation (8) reflects the equilibrium of real money balances as a function of the real price of energy and the nominal level of money balances, where the fixed real price of the real price of energy, real money balances are exogenous to changes in the nominal money stock. From Equations (3) and (7), the average of the domestic price d_t can be formed:

$$d_t = m_t + \bar{S} + \phi\tilde{r}_t, \quad \text{where } \phi = \mu\tfrac{\psi}{\xi} - (1-\mu), \quad \bar{S} = \frac{s_t}{\xi} \text{ and } \tilde{r}_t = r_t - d_t; \tag{9}$$

$\tilde{r}_t$ is an alternative representation of the exogenous real price of energy, for $\tilde{r}_t$ to be inflationary, ϕ must be positive, hence the direct impact of energy prices on the price level $(1-\mu)$ must be minimum. This suggests that the pass-through impact has not been completed (stickiness in prices).

Additionally, as postulated by Rotemberg (1983), if the normal price of oil is fixed, an increase in the money balance (m_t) would lead to an increase in the price level (p_t), a decrease in the real price of energy, a rise in output (with conditions), an increase of the domestic price (d_t) and a reduction of the demand at t.

3.1.2. *Model in the presence of costs of changing prices*

When the price changes are costly, a firm must first compute the difference between sales revenues and the costs of production by using a quadratic function of p_{it}, as highlighted by Rotemberg (1982):

$$\pi\left(\frac{P_{it}}{P_t}\right) \approx \pi\left(\frac{P^*_{it}}{P_t}\right) - w_i(P_{it} - P^*_{it})^2, \tag{10}$$

where π represents the difference between real sales revenues and the real costs of production and w_i is a constant. Rotemberg (1982) argued that in the presence of changing costs, the effects of price changes may be captured with the quadratic cost of changing prices, as per the following equation:

$$E_t \sum\nolimits_{\tau=t}^{\infty} \rho^{\tau-t}\left[\pi\left(\frac{P^*_{it}}{P_\tau}\right) - w_i(p_{i\tau} - p^*_{i\tau})^2 - c_i(p_{i\tau} - p_{i\tau-1})^2\right], \tag{11}$$

with ρ being the discount factor, as indicated by Rotemberg (1983), hence the maximization of Equation (11) would be as follows:

$$\rho_{it} = \alpha P_{it-1} + \frac{1}{\beta\rho c}\sum\nolimits_{j=0}^{\infty}\left(\frac{1}{\beta}\right)^j P^*_{\frac{it}{t}+j}, \tag{12}$$

where

$$\alpha + \beta = 1 + \frac{1}{\rho} + \frac{1}{\rho c}, \quad \text{hence } \alpha\beta = \frac{1}{\rho},\ \alpha < 1, \beta > 1,$$

where $P^*_{\frac{it}{t}+j}$ is the value of p^*_{it+j} expected by firm i at time t. Because in the presence of cost of changing prices, firm i does not want to charge at t a price too different from the price it charges at $t-1$.

The equilibrium price for firms which have rational expectations can be computed using the techniques highlighted by Rotemberg (1983). It is given by

$$d_t = \gamma d_{t-1} + \frac{\xi}{\delta\rho c}\sum_{j=0}^{\infty}\left(\frac{1}{\delta}\right)^2\left[\bar{S} + m_{\frac{t}{\tau}+j} + \phi\tilde{r}_{\frac{t}{\tau}+j}\right], \tag{13}$$

where $m_{\frac{t}{\tau}+j}$ and $\tilde{r}_{\frac{t}{\tau}+j}$ are the mathematical expectations of m_{t+j} and $\tilde{r}_{t+j}$. Considering that both money supply (m_t) and the relative price of energy $(\tilde{r}_t)$ follow a random walk, then

$$m_t = m_{t-1} + \varepsilon_t; \quad V_j; \quad m_{\frac{t}{\tau}+j} = m_t, \tag{14}$$

$$\tilde{r}_t = \tilde{r}_{t-1} + v_t; \quad V_j; \quad \tilde{r}_{\frac{t}{\tau}+j} = \tilde{r}_t, \tag{15}$$

where ε_t and v_t are independently and identically distributed (i.i.d.) with mean zero and finite variance, therefore

$$d_t = \gamma d_{t-1} + (1-\gamma)(\bar{S} + m_t + \phi\tilde{r}_t). \tag{16}$$

Domestic price (d) is expected to adjust slowly if the energy price increments are inflationary, then ϕ is positive and a positive shock, ϵ_t, leads to a gradual increase in domestic prices. Hence

$$q_t = \bar{A} + f(m_t - d_t) + [k\mu - d(1-\mu)]\tilde{r}_t. \tag{17}$$

From Equation (17), a gradual increase in d_t induces a gradual fall of the aggregate output q_t. Besides, an increase in the relative price of energy $(\tilde{r}_t)$ will eventually lead to a gradual fall of the domestic prices, d_t.

In conclusion, the intuition behind both models indicates that the price adjustment process may not be complete after oil price fluctuations due to the presence of the costs of changing prices. Hence, this is in parallel with our argument, where the relationship between oil price fluctuations and inflation is asymmetric.

3.2. *Model*

The model of this study is as follows:

$$\text{PI} = f\ (\text{OP}, \text{import}, \text{GDP}), \tag{18}$$

where PI is the inflation rate (producer price index), OP is the oil price, in local currency (Indonesian Rupiah), and import represents the net imports of goods and services. GDP represents the GDP growth rate.

The empirical model of this study outlines the influence of the global oil price on the inflation rate of Indonesia through the asymmetric cointegration approach, as suggested by Shin *et al.* (2014) and utilised by Goh *et al.* (2020). This approach uses the NARDL cointegration approach to capture both the long-run and short-run asymmetries between the global oil price and the inflation rate. Besides, we also included the GDP.

The asymmetric long-run equation of the inflation rate is as follows:

$$\text{PI}_t = \alpha_0 + \alpha_1\text{OP}_t^+ + \alpha_2\text{OP}_t^- + \alpha_3\text{import}_t + \alpha_4\text{GDP}_t + \varepsilon_t, \tag{19}$$

where α_0, α_1, α_2, α_3 and α_4 are cointegrating vectors or are vectors of the long-run parameters to be estimated. Whereas, OP_t^+ and OP_t^- are partial sums of the positive and negative changes in OP,

$$\text{OP}_t^+ = \sum_{i=1}^{t} \Delta\text{OP}_t^+ = \sum_{i=1}^{t} \max(\Delta\text{OP}_i, 0) \tag{20}$$

and

$$\mathrm{OP}_t^- = \sum_{i=1}^{t} \Delta\mathrm{OP}_t^- = \sum_{i=1}^{t} \max(\Delta\mathrm{OP}_i, 0), \tag{21}$$

where

$$\mathrm{OP}_t = \mathrm{OP}_0 + \mathrm{OP}_t^+ + \mathrm{OP}_t^-. \tag{22}$$

Based on the above formulation, the long-run relationships between inflation rate (producer price index) and the oil price are α_1 and α_2, where α_1 captures the long-run relationship between inflation rate and the oil price increments and α_2 captures the long-run relationship between inflation rate and the oil price reductions. By default, Equation (22) indicates that the current value of the oil price (OP_t) variable is given by the sum of its initial value and the positive and negative partial sums.

In the empirical implementation, the long-run equation (19) in an ARDL model, as per Shin *et al.* (2014), is as follows:

$$\begin{aligned}\Delta PI_t = {} & \beta_0 + \beta_1 PI_{t-1} + \beta_2 OP_{t-1}^+ + \beta_3 OP_{t-1}^- + \beta_4 import_{t+1} + \beta_5 GDP_{t-1} \\ & + \sum_{i=1}^{p} \varphi_i \Delta PI_{t-i} + \sum_{i=0}^{q} (\theta_i^+ OP_{t-i}^+ + \theta_i^- OP_{t-i}^-) + \sum_{i=0}^{r} \gamma_i \Delta import_{t-1} \\ & + \sum_{i=0}^{s} \delta_i \Delta GDP_{t-1} + \mu_t. \end{aligned} \tag{23}$$

All of the variables were defined as above, with the addition of p, q, r and s which were the lag orders. The long-run parameters in Equation (19) were derived from Equation (23), i.e., $-\beta_2/\beta_1 = \alpha_1$ and $-\beta_3/\beta_1 = \alpha_2$. Besides, $\sum_{i=0}^{q} \theta_i^+$ measured the short-run influences of oil price increments on the inflation rate, while $\sum_{i=0}^{q} \theta_i^-$ measured the short-run influences of oil price reductions on the inflation rate.

The implementation of the nonlinear ARDL analysis is made using the following steps. First, similarly to the ARDL error correction model (ECM), proposed by Pesaran *et al.* (2001), the NARDL model does not allow $I(2)$ variables. The presence of $I(2)$ variables will cause the computed F-statistics for the cointegration test to be invalid. Hence, the Augmented Dickey–Fuller (ADF) and Philips–Perron (PP) unit root tests were carried out to confirm that all of the variables were $I(0)$ or $I(1)$. The Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test was also included to confirm the findings obtained from the ADF and PP unit root tests. Second, Equation (23) was estimated using the standard Ordinary Least Squares (OLS) estimation method. Third, we ran the nonlinear error correction model under the NARDL model, using a two-step least-square estimation, to obtain the optimum lags for the NARDL model. Fourth, to test for cointegration under the NARDL model, the bounds testing approach, suggested by Pesaran *et al.* (2001) and Shin *et al.* (2014), was carried out to identify the presence of cointegrating variables. Next, we performed the Wald test under the restriction $-\beta_2/\beta_1 = -\beta_3/\beta_1$ to examine the presence of asymmetry on the long-run impact of oil price on the inflation rate in Indonesia. Lastly, we checked the robustness of the estimation with serial correlation and stability diagnostic tests.

3.3. *The data*

Quarterly data from 1991 to 2019 were employed in the analysis. The inflation rate was represented by the producer price index and the data was taken from the International Monetary Fund (IMF) databank. The producer price index was chosen over the consumer price index as the proxy for inflation in this study, based on three factors. First, Indonesia is observing inflation targeting strategies, where Bank Indonesia is committed to maintaining price stability to keep the inflation within the range of a target corridor, for instance, at $(4.0 \pm 1)\%$ (2017) and $(3.5 \pm 1)\%$ (for both 2018 and 2019). Hence, the general price index that is captured by the CPI is exogenous from oil price fluctuations, as they may be subjected to subsidies and price control policies. Second, the PI focuses on the entire output of producers in Indonesia, which includes the goods and services purchased by producers as inputs in their operations, or as investments, and the goods and services bought by consumers from retail sellers and directly from producers. Hence, this is in parallel with our production function framework which highlights the role of oil price fluctuations in the production process flow. Lastly, in the producer price index, sales and taxes are not included in the producers' returns, whereas the consumer price index includes taxes and sales, hence, we felt that PI was a better proxy for inflation, as it represents the true value of prices for goods and services.

The level of OP was taken from the World Bank Commodity Price Data (The Pink Sheet) and the exchange rate (USD to Indonesian rupiah) was taken from the International Financial Statistics (IFS) databank. The oil price, in the local currency, was utilized in this study to enable us to capture the impact of oil price fluctuations on the domestic oil-based production processes and variations in transportation costs, as highlighted in the production function (Figure 1). Importation, which highlights the inflow of goods and services, was included in our study to capture direct (importation of oil-based products, or inputs) and indirect (fluctuations in shipment/transportation costs) impacts of oil price fluctuations on the PI and the data was taken from the Federal Reserve Economic Data (FRED). Lastly, the GDP growth rate was included to showcase the economic activity (productivity) in Indonesia, where a higher GDP growth rate indicated higher productivity and a greater efficiency level, hence having a direct impact on the PI. The GDP data was taken from the Asian Regional Integration Centre of the Asian Development Bank. Table 1 presents the descriptive statistics of the inflation rate and the oil price, in the local currency. The standard deviations of all of the variables were high, which indicated that all of the

Table 1. Summary Statistics

Variable	Mean	Std. Dev	Min	Max	Observations
Inflation (PI)	71.09	53.00	9.34	167.95	119
Oil Price in IDR* (OP)	472,926.10	376,066.70	392,414.60	1,291,110.00	119
GDP	5.19	4.10	−18.26	11.42	119
import	2.80E+10	1.77E+09	7.11E+09	6.04E+10	119

Note: *IDR represents Indonesian rupiah, GDP represents the GDP growth rate.

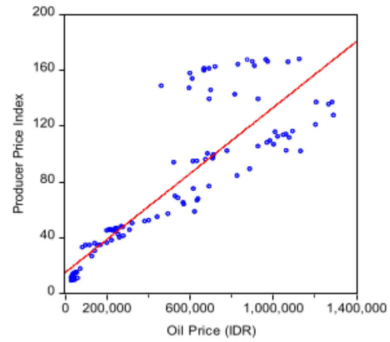

Figure 2. Scatter Plot of Oil Price Versus the Producer Price Index of Indonesia

variables had high variation. Figure 2 depicts the time scatter plots of both series, the PI and the oil price, and shows a positive correlation over time.

4. Empirical Results and Discussion

Similarly to the ARDL error correction model, as proposed by Pesaran *et al.* (2001), the NARDL model does not allow $I(2)$ variables. Hence, we employed the ADF and PP unit root tests on each variable to confirm that no $I(2)$ variables were involved in the analysis. Additionally, the KPSS test was also included to confirm the findings obtained from the ADF and PP unit root tests. The results of the tests are reported in Table 2. The ADF,

Table 2. ADF and PP Unit Root Test Results

Variable	Level			First Difference		
	ADF	PP	KPSS	ADF	PP	KPSS
PI	−1.1784	−1.1856	0.2340***	−6.2630***	−7.4627***	0.0868
	(0.9097)	(0.9084)		(0.0000)	(0.000)	
OP	−1.7516	−1.3719	0.2380***	−9.3673***	−9.3083***	0.0854
	(0.7218)	(0.8643)		(0.0000)	(0.0000)	
GDP	−3.2043*	−3.2043*	0.1310*	−11.3560***	−11.4479***	0.0341
	(0.0886)	(0.0866)		(0.0000)	(0.0000)	
import	−1.9410	−2.1119	0.1191*	−9.2288***	−9.1308***	0.0661
	(0.6267)	(0.5336)		(0.0000)	(0.0000)	
CPI	−0.6125	−0.7216	0.2943***	−6.0263***	−5.5972***	0.0608
	(0.9762)	(0.9687)		(0.0000)	(0.0000)	

Notes: PI represents the producer price index, as a proxy for inflation. OP is the oil price, in local currency. GDP represents the GDP growth rate and import represents the net imports of goods and services. CPI represents the consumer price index. The coefficients displayed are the t-statistics obtained from the EViews software. The null hypotheses of the ADF and PP unit root tests and the null hypothesis of the KPSS test are stationarity. The constant and trend terms are included in the test equation and the SIC is utilized for the optimal lag order in the ADF test equation. The values in parentheses are the p-values. ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

PP and KPSS unit root tests were in agreement that the inflation rate and the oil price were integrated at order 0 or order 1. The absence of $I(2)$ variables was vital, as such data would have invalidated the computed F-statistics for testing cointegration. The absence of $I(2)$ variables allowed us to proceed to perform the NARDL model estimation, as suggested by Pesaran *et al.* (2001).

The cointegration tests on the oil price–inflation nexus equation were performed by regressing Equation (23) with the OLS estimation method and the nonlinear ECM, under the setting of the NARDL model, through the two-step least-square method, to arrive at the model's final specification. Table 3 summarizes the results of the model specification. In the NARDL framework, the existence of long-run cointegration can be tested with bounds testing F-statistics, as suggested by Shin *et al.* (2014), to compare with the critical values provided by Pesaran *et al.* (2001), for observations greater than 100. If the calculated F-statistics are greater than the upper-bound critical value, then there is evidence of cointegration. From the results presented in Table 4, the F-statistics that were reported were significant at the 10% significance level, thus rejecting the null hypothesis of non-cointegration. Additionally, the p-value of the long-run asymmetry test was less than 0.01, thus indicating an asymmetry in the long-run impact of oil price on the inflation rate of Indonesia.

Table 3. Nonlinear ADRL Estimation Results (Dependent Variable: PI)

	Oil Price	
Independent Variable	Coefficient	p-Value
Constant	0.0628	0.8460
PI(−1)	−0.1446***	0.0023
OP_POS(−1)	0.0642***	0.0017
OP_NEG(−1)	0.0309***	0.0017
import(−1)	0.0128	0.3114
GDP(−1)	−0.0189*	0.0807
ΔPI(−2)	0.2212***	0.0006
ΔOP_POS	0.2572***	0.0000
ΔOP_POS(−1)	0.1276***	0.0004
ΔOP_NEG	0.0832**	0.0212
Δimport(−4)	−0.0778**	0.0285
ΔGDP	−0.0301***	0.0054
ΔGDP(−1)	−0.0451***	0.0004

Notes: PI represents the producer price index, as a proxy for inflation. OP is the oil price, in local currency. GDP represents the GDP growth rate and import represents the net imports of goods and services. The figures in parentheses are the p-values. ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

Table 4. Long-Run Cointegration Test, Asymmetric Test and LM Test Results (Dependent Variable: PI)

Countries		ARDL Bounds Test (Narayan, 2005)		Long-Run Asymmetric Test		Breusch–Godfrey Serial Correlation LM Test	
	F-statistics	Coefficient	p-Value	Lag 2	p-Value	Lag 4	p-Value
Test Statistics	3.5900*	22.5629***	0.0000	0.3399	0.7127	0.2067	0.9342
Pesaran *et al.* (2001) ($K = 4$, $n = 119$)	Lower Bound	Upper Bound					
1%	3.74	5.06					
5%	2.86	4.01					
10%	2.45	3.52					

Notes: The test statistics of the cointegration tests were compared against the critical values reported in Pesaran *et al.* (2001). ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

The results presented in Table 4 are not the long-run coefficients; to obtain the long-run coefficients, we divided the negative coefficient of each of the explanatory variables by the coefficient of PI (−1). The long-run coefficients of the explanatory variables are presented in Table 5. The long-run coefficients presented in Table 5 indicate that a 1% increase in the oil price rate led to a 0.4436% increase in the inflation rate (positive relationship), and a 1% decrease in the oil price led to a 0.2137% decrease in the inflation rate (positive relationship as well). Therefore, the inflation rate responded more significantly to a positive change, rather than to a negative change, in the oil price (as shown in Figure 3 — NARDL Multiplier Graph). Besides, the pass-through effect of oil price on the inflation rate was not complete, as a 1% increase in the oil price was associated with only a 0.26% increase in the inflation rate. The incomplete pass-through effect could be due to the inflation targeting policy observed in Indonesia; as an example, President Joko Widodo ordered energy prices to be kept flat in 2018 and 2019 by increasing the fuel subsidies (Reuters, 2019). Nevertheless, as highlighted in the theoretical background, the impact of oil price on the producer price index remains significant, transportation charges and production inputs imported from overseas are still subject to the effects of oil price fluctuations. However, surprisingly, the coefficients obtained from the import variable were not significant at the conventional significance level, whereas the GDP growth rate was significant and inversely

Table 5. Long-Run Coefficients (Dependent Variable: PI)

Countries	Long-Run Coefficients							
	OP_ Pos	p-Value	OP_Neg	p-Value	Import	p-Value	GDP	p-Value
Test Statistics	0.4436***	0.0017	0.2137***	0.0017	0.0884	0.3114	−0.1309*	0.0807

Note: ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

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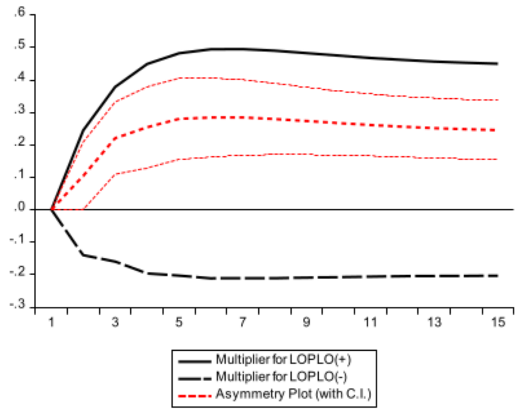

Figure 3. NARDL Multiplier Graph

associated with PI. This indicates that a higher GDP growth rate leads to a lower producer price index in Indonesia. This could be explained from the perspective of the production approach, where higher productivity reflects a higher efficiency level, thus leading to a lower producer price index. However, the insignificance of imports to the producer price index indicates that further research on the roles of imports with regard to the producer price index of Indonesia is needed.

Additionally, we included the Breusch–Godfrey serial correlation LM statistics for autocorrelation, up to order 4, to serve as the diagnostic statistics to justify the adequacy of the model specification. The results are presented in the right columns of Table 4. We also present, in Figure 4, the CUSUM and CUSUM-of-squares statistical diagrams for testing the structural stability of the model. From the results that unfold in Table 4, both coefficients confirmed the absence of autocorrelation. The diagrams of CUSUM and CUSUM of squares indicate that the test statistics were within the 5% confidence interval bands, suggesting that there was no structural instability in the residuals.

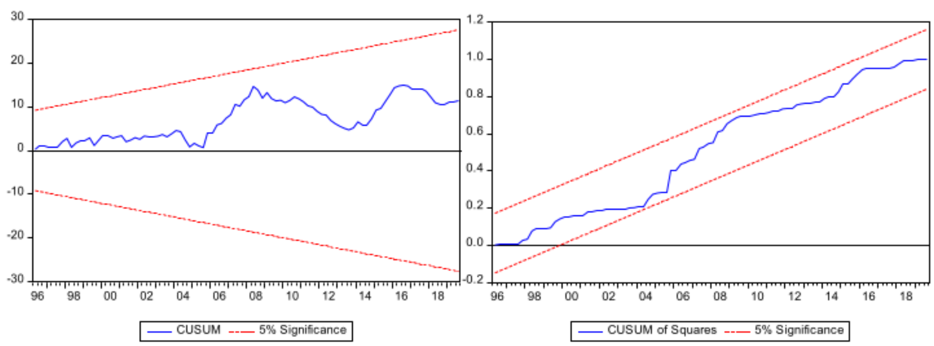

Figure 4. Structural Stability Test: CUSUM and CUSUM of Squares

4.1. *Robustness checking*

To verify the robustness of our analysis, and to confirm that producer price index was the right indicator for the rate of inflation for a country implementing an inflation targeting policy, the impact of oil price on the CPI was included in this study and the estimations are presented in Tables 6–8. Table 6 summarizes the results of the model specification, whereas Table 7 reports the results of long-run cointegration test, as well as asymmetric test findings and the Breusch–Godfrey serial correlation LM test results. Lastly, the long-run coefficients of the explanatory variables are presented in Table 8.

The results presented in Table 7 are consistent with the estimation results obtained by the producer price index–oil price nexus. The oil price and the CPI were found to be significantly integrated in the long run at the 10% significance level. However, the *p*-value of the long-run asymmetry test was more than 0.10, thus indicating that there was no asymmetry in the long-run impact of oil price on the consumer price index. The finding is in parallel with the inflation targeting policy of Indonesia, where the consumer price index

Table 6. Nonlinear ADRL Estimation Results (Dependent Variable: CPI)

Independent Variable	Oil Price	
	Coefficient	*p*-Value
Constant	0.1561	0.4301
CPI(−1)	−0.0396	0.1272
OP_POS(−1)	0.0159	0.1071
OP_NEG(−1)	0.0130**	0.0309
import(−1)	0.0006	0.9353
GDP(−1)	−0.0216**	0.0102
ΔCPI(−1)	0.2518***	0.0021
ΔCPI(−3)	−0.2439***	0.0018
ΔOP_POS(−1)	0.0603***	0.0046
ΔOP_POS(−2)	0.0341	0.1187
ΔOP_NEG(−3)	−0.0207***	0.0030
Δimport	−0.0523**	0.0103
Δimport(−3)	0.0377*	0.0775
Δimport(−4)	−0.0484**	0.0210
ΔGDP	−0.0114*	0.0788
ΔGDP(−1)	−0.0174**	0.0223
ΔGDP(−2)	−0.0126*	0.0826
ΔGDP(−3)	−0.0207***	0.0030

Notes: CPI represents the consumer price index as a proxy for inflation. OP is the oil price in local currency. GDP represents the GDP growth rate and import represents the net imports of goods and services. Figures in parentheses are the *p*-values. ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

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Table 7. Long-Run Cointegration Test, Asymmetric Test and LM Test Results (Dependent Variable: CPI)

Countries		ARDL Bounds Test (Narayan, 2005)		Long-Run Asymmetric Test		Breusch–Godfrey Serial Correlation LM Test
	F-statistics	Coefficient	p-Value	Lag 2	p-Value	Lag 4	p-Value
Test Statistics	3.9219*	0.2686	0.6054	0.9990	0.3721	0.5776	0.6796
Pesaran *et al.* (2001) ($K = 4$, $n = 119$)	Lower Bound	Upper Bound					
1%	3.74	5.06					
5%	2.86	4.01					
10%	2.45	3.52					

Notes: The test statistics of the cointegration tests were compared against the critical values reported in Pesaran *et al.* (2001). ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

Table 8. Long-Run Coefficients (Dependent Variable: CPI)

Countries	Long-Run Coefficients							
	OP_ Pos	p-Value	OP_Neg	p-Value	Import	p-Value	GDP	p-Value
Test Statistics	0.4000	0.1272	0.3270**	0.0309	0.0164	0.9353	−0.5456**	0.0102

Note: ***, ** and * denote the significance at the 1%, 5% and 10% levels, respectively.

is controlled by Bank Indonesia to sustain at the $(3.5 \pm 1)\%$ level. Hence, the impact of oil price fluctuations will not matter to the consumer price index. On the other hand, the long-run coefficients of the explanatory variables, as presented in Table 8, indicated that the import variable was not significant at the conventional significance level, whereas the GDP growth rate was significant. This is identical to the finding of the producer price index–oil price nexus.

4.2. *Discussion*

This subsection presents the main implications of the results obtained from the empirical analysis and robustness checking.

From the results, which are summarized in Table 4, oil prices were found to be significantly cointegrated with the rate of inflation, as measured by the producer price index, hence we suggest that the oil price is a significant determinant of the inflation rate, even in a country that is observing an inflation targeting policy. Additionally, the oil price was found to be asymmetrically correlated with the inflation rate in Indonesia, suggesting that the inflation rate in Indonesia reacts differently to upward and downward fluctuations in the oil price. More specifically, as reported in Table 5, a 1% increase in the oil price tended to

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increase the rate of inflation of Indonesia by 0.4436 percentage points, whereas a 1% decrease in the oil price tended to decrease the inflation rate by 0.2137 percentage points. This finding suggested that the general price level reacted with more sensitivity to increments, rather than to reductions in the oil price.

The results from robustness checking highlighted that the oil price was integrated with the consumer price index of Indonesia, but no asymmetric cointegration was found, hence suggesting that the oil price was a significant determinant of the consumer price index. We argued that, under the inflation targeting policy and heavy fuel subsidies [47 trillion rupiahs in 2017 and 46.9 trillion rupiahs in 2018 (Indonesia-Investment, 2018)] of the Indonesian government, the consumer price index was not expected to be sensitive to oil price fluctuations. This can be explained by the definition of CPI itself, where CPI is a measure that examines the weighted average of prices of a basket of consumer goods and services, such as transportation, food and medical care. Hence, in the presence of fuel subsidies, the direct impact of oil price fluctuations was being absorbed by the government through these subsidies. However, as presented in the theoretical background, the oil price can affect the general price levels in various ways. Thus, it would be misleading for us to conclude that the oil price was not a significant determinant of the inflation rate in Indonesia. Hence, for countries with inflation targeting policies, the PI, which measures the average change over time in the selling prices received by domestic producers of goods and services, should be the rightful proxy for the rate of inflation, instead of the CPI.

5. Conclusion

Recognizing that oil price fluctuations may impact general prices in several ways, this paper adopted the NARDL model, as proposed by Shin *et al.* (2014), to capture the presence of asymmetric cointegration between the inflation rate (proxied by the producer price index) and the oil price in Indonesia. The empirical results indicated that there was a significant evidence of asymmetric effects of the oil price on the rate of inflation in the Indonesian economy. More specifically, an increase in the oil price tended to lead to an increase in the inflation rate with a greater deviation, while an oil price reduction would lead to a decrease in the inflation rate, with a lower deviation. Therefore, the rate of inflation responded more to positive changes, rather than to negative changes, in the oil price.

On the other hand, the oil price was not a significant determinant of the consumer price index, hence suggesting that the consumer price index was not an appropriate variable to proxy the inflation rate of a country that was observing an inflation targeting policy, as well as providing heavy fuel subsidies. The impact of oil price fluctuations was absorbed by the government through subsidies, thus the domestic price level, which is captured by the CPI, would not vary much. Theoretically, oil price fluctuations vary transportation costs and input prices from overseas and will affect the producer price index. Hence, the producer price index is a more appropriate variable to proxy the inflation rate of a country which is observing an inflation targeting policy, as well as providing heavy fuel subsidies.

As previously pointed out, the inflation rate responds more to positive changes in the oil price which indicates that the speed of adjustment in price increments is faster than when the oil price drops. This suggests that the benefits of oil price reductions are not fully passed down to the consumers, which is in agreement with Rotemberg's (1983) price stickiness hypothesis. Thus, our first policy implication is that policymakers should pay more attention to combat profiteering. Policymakers should enforce strict regulations and penalties on companies/producers who make or seek to make an excessive or unfair profit. For example, the government could reduce or prevent profiteering through an "Anti-Profiteering Act".

Additionally, the GDP growth rate was found to be negatively and significantly associated with the producer price index, which indicates that a growing GDP rate, associated with high productivity and efficiency levels, has a corrective effect on the inflation rate in Indonesia. Given that Indonesia's total estimated population is approximately 273 million people, the world's fourth most populous nation, with the development of human capital also seen as a key factor for economic growth, development and competitiveness (World Economic Forum, 2017), policymakers should prioritize human capital development and initiate programs such as improving the levels of education, health and social protection.

Lastly, with depleting domestic oil reserves in combination with increased domestic oil demand, Indonesia has turned into a net oil importer, since the year 2004. Hence, the Indonesian government should not continue to rely on nonrenewable energy sources and should explore the potential of renewable energy sources, such as solar energy and geothermal energy. This would, at the same time, enhance the green credentials of the country, whilst reducing the effects of fluctuations in the oil price on the economy of the country. Besides, Indonesia, with its 18,037 islands, has an estimated total potential for offshore wind energy of 9.3 GW, according to the International Renewable Energy Agency (IRENA). To date, the World Bank has approved US$150 million in loans for Indonesia to scale up investments in geothermal energy by reducing the risks of early-stage exploration. The loan is accompanied by US$127.5 million in grants from the Green Climate Fund and the Clean Technology Fund, two institutions supporting climate-friendly development (World Bank, 2019). Thus, policymakers should gradually reduce the existing fuel subsidies, whilst increasing government spending to develop renewable and sustainable energy industries. Lastly, policy attention should also be directed to increasing production efficiency through research and development and innovations. Theoretically, an increase in efficiency will shift the production frontier to the right and will lead to a reduction in unit production costs (Sickles and Zelenyuk, 2019). This should be able to act as a buffer to the impact of oil price fluctuations.

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