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EXAMINING THE EFFECT OF OIL PRICE PASS-THROUGH ON THE DOMESTIC PRICES: ASYMMETRIC VERSUS SYMMETRIC ADJUSTMENT MODELLING

(Memeriksa Kesan Penembusan Harga Minyak Terhadap Harga Domestik: Pemodelan Pelarasan Tak Simetri Langsung lawan Simetri)

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ABSTRACT

We study the effect of oil price pass-through on the domestic prices, namely on the consumer price index (CPI) and producer price index (PPI), based on the asymmetric adjustment modelling approach. The behaviour of domestic prices in response to oil price changes was examined by comparing two groups of economies, namely the oil-importing versus oil-exporting countries. The results show that although the oil price has a significant influence on the domestic price inflation in the short-run and in the long-run for most of the oil-importers and oil-exporters, it is not the main factor affecting CPI and PPI inflation. Moreover, oil price inflation seems to trigger a higher impact on PPI inflation than CPI inflation. The pass-through of oil prices on CPI inflation is low, especially in the oil-importing countries while the main determinant of CPI and PPI inflation is gross domestic product (GDP). The results are found to hold for both groups of countries.

Keywords: oil price; asymmetric adjustment modelling; domestic price inflation

ABSTRAK

Kajian ini bertujuan menyiasat penentu utama inflasi harga domestik dan melihat kesan penembusan harga minyak ke atas harga domestik, iaitu ke atas indeks harga pengguna (CPI) dan indeks harga pengeluar (PPI), menggunakan pendekatan pemodelan pelarasan tak simetri langsung. Tingkah laku harga domestik dalam memberi tindak balas terhadap perubahan harga minyak diperiksa dengan membandingkan dua kumpulan ekonomi, iaitu negara pengimport minyak dan negara pengeksport minyak. Keputusan menunjukkan walaupun harga minyak bukanlah faktor utama yang mempengaruhi inflasi CPI dan PPI, ia mempunyai pengaruh penting pada inflasi harga domestik di kebanyakan negara pengimport minyak dan pengeksport minyak dalam jangka pendek dan jangka panjang. Tambahan pula, inflasi harga minyak juga dilihat cenderung untuk mencetuskan kesan yang lebih tinggi pada inflasi PPI berbanding dengan inflasi CPI. Penembusan harga minyak pada inflasi CPI adalah rendah, terutama dalam kalangan negara pengimport minyak manakala penentu utama inflasi CPI dan PPI adalah keluaran dalam negara kasar (GDP). Keputusan ini didapati terpakai untuk negara-negara daripada kedua-dua kumpulan.

Kata kunci: harga minyak; pemodelan pelarasan tak simetri langsung; inflasi harga domestik

1. Introduction

The inflationary consequences due to movement in international oil prices have alerted the policymaker in their policy design and decision as oil price movement may affect the proper conduct of monetary policy and economic performance. Hence, it is important to understand the effect of oil price pass-through on domestic prices. The effect that oil price shocks have on inflation is known as a "pass-through" effect. It is well-documented in the historical reports and

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research papers that oil price changes can have a significant effect on the economy especially in terms of domestic price stability. However, results may differ across countries and periods. The oil price pass-through on inflation tends to depend on how important energy is in the economy. The disparity in the degree of energy intensity might lead to different responses in both production and consumption across countries.

In this paper, we study the impact of oil prices on domestic price changes at consumer and producer levels (consumer price index (CPI) and producer price index (PPI)). Our main objective is to detect the symmetric/asymmetric cointegrating relationship between oil prices and domestic prices for both top oil-importers and oil-exporters. In particular, we aim to find out how the effect of oil price changes on domestic prices differs due to the oil dependency factor.

Our results report the existence of a symmetric long-run relationship between prices of oil and domestic in several countries but no asymmetric relationship is found. The results also reveal that oil price imposes a significant pass-through effect on domestic inflation in most of the oil-importing and exporting countries in both the short-run and long-run. However, the oil price is not the main cause of domestic price inflation. Although oil price may pass-through into higher production cost and causes higher inflation at the producer level, its impact on consumer price level is very small. In some cases, higher oil price is associated with lower consumer price inflation due to price rigidity and the effective monetary policy to maintain price stability. Other factors (gross domestic product (GDP), PPI and CPI) can have a larger influence on domestic price inflation.

The rest of the paper is organized as follows. Section 2 presents the literature review and theoretical framework. Section 3 explains the methodology and outlines the empirical approach. Section 4 summarizes the findings. Finally, Section 5 draws a main conclusion.

2. Literature Review and Theoretical Framework

Previous studies provided different theoretical explanations on the relationship between oil prices and the level of economic activity. According to Sek (2017), oil price shocks may impact economic activity through various transmission channels. On the supply side channel, rising oil prices may result in an increase in production cost since oil acts as a basic input of most primary commodities. This implies that output and productivity will decrease. Consumer price will then increase, leading to higher inflation. On the demand side channel, changes in oil prices mainly affect consumption. An increase in oil price indicates reduced purchasing power and disposable income, which then leads to lower consumption. The final transmission channel is through monetary and fiscal policies channels. High employment and price stability have always been the main concern of policymakers in response to oil price changes which might lead to inflation or recession. For instance, policymakers may tighten monetary policy during inflation and expands monetary policy during a recession.

Oil price effects can be in the forms of the direct, indirect and second round. For instance, the higher oil prices in oil-importing countries may lead to higher concern regarding uncertainty about a future reduction in employment and real income, causing consumers to increase their precautionary saving and hence lower the consumption. In this case, consumer expenditure is directly affected by oil price changes. The indirect effect of oil price is related to the patterns changed in consumption expenditures. The uncertainty effect which causes a shift in expenditure pattern mentioned above may trigger sectoral shifts through the economy. This is because changing in consumption expenditures will lead to labour and capital the reallocation from declining sectors to expanding sectors, which is called reallocation effect. Lastly, an oil price increase may generate a second round effect. While firms could pass on the increased cost of production to the consumers by increasing the price for goods and services, workers could also request higher wages to compensate for the increasing living cost. This wage-price spiral may in turn, result in higher inflation (Edelstein & Kilian 2009).

However, the above-mentioned scenarios of impacts experienced by different countries may be different, mainly depending on the oil dependency of a country. This is because, in oil-exporting countries, oil is the main source of revenue and in oil-importing countries, oil is an important input used in their production. As discussed by Ibrahim and Said (2012), in terms of supply, increasing oil price which results in lower productivity, declining total output and increasing unemployment rate cause oil-importing countries to suffer. On the other hand, a rise in the oil price which increases investment opportunities, and consequently stimulates output growth and decreases the unemployment rate induce oil-exporting countries to get higher revenues. In sum, oil-exporting countries generally gain from increasing oil prices as compared to oil-importing countries.

From the explanation above, despite the theoretical explanations we have, the effects of oil price changes on the economy are varying due to the economic features/ conditions and dependency/ intensity on oil and. Hence, we also provide an empirical literature review on the impacts of oil price changes on domestic price changes. We roughly classify the empirical findings on the impacts of oil price volatility into three areas.

First, majority studies examined the effects of oil price shocks on inflation and economic growth represented by CPI, GDP and other indices through a macroeconomic view. However, these studies reported very contradictory results as to whether oil price shocks affect inflation and economic growth in the countries studied. For instance, Gao *et al.* (2014) examined how oil price shock pass-through into six CPI sub-indices in the US by using VAR technique. The result showed that oil price shock is more influential in energy-intensive sectors but the effect is limited in less energy-intensive sectors. In addition, Ibrahim and Chancharoenchai (2014) examined the relationship between oil price and price indices of Thailand using both symmetric and asymmetric cointegration approaches. The finding showed that the oil price effect is dominant in the energy sector followed by the transportation and communication and the non-raw food price sectors. Contrary to the above, research of L'oeillet and Licheron (2008) on the Euro area by using the augmented backward Philips curve also found diminished pass-through of oil price to inflation due to declining energy intensity. On the other hand, Hooker (2002) applied the Philips curve framework to study the effects of oil price changes on US inflation concluded that since 1980, the effect of oil prices pass-through into the domestic prices in the US is very limited.

Second, many studies analysed the relationship between oil prices and commodities. Most of these studies employed OLS or ARDL, either linear or nonlinear. We can conclude that the effects of oil price shocks are different among agricultural commodities. For example, Baffes (2007) used OLS regression to investigate the influences of crude oil prices across prices of 35 internationally traded primary commodities between 1960 and 2005. He found a strong impact of an oil price change on the food price index. Likewise, Ibrahim (2015) analysed the relations between food and oil prices using the data of Malaysia from 1971 to 2012 by using a nonlinear ARDL model. His finding supported that there exists positive long-run relation with oil price increases and food price but not with oil price decreases and food price. While many studies found a significant impact of oil prices on commodity prices, Zhang *et al.* (2010) indicated that there is no direct relationship between energy prices (ethanol, gasoline, and oil) and agricultural commodity price (corn, rice, soybeans, sugar, and wheat). Similar evidence is also documented for the commodity price by Nazlioglu and Soytas (2011). After investigating the relationship between oil prices, the exchange rate of dollar-lira and agricultural prices (wheat, soybeans, cotton, maize, and sunflower) from January 1994 to March 2010, Nazlioglu and Soytas (2011) found neutrality of Turkey agricultural commodity prices to oil price fluctuations.

The third stream of research regarding oil price transmission concentrates on comparing the influence of oil price shocks between oil-importers and oil-exporters which has not been extensively done in the past. For instance, Filis and Chatziantoniou (2014) focused their analyses on net oil-importing and net oil-exporting countries. They concluded that oil importers tend to face a higher negative effect due to oil price increases compared to oil exporters. A recent study by Sek *et al.* (2015) on two groups of countries, i.e. high versus low oil dependency countries from 1980 to 2015. The results reported a direct effect from oil price on inflation in low oil dependency countries but the indirect effect was found in high oil dependency countries through changes in the exporters' production cost. In contrast, Herrera *et al.* (2015) conducted a study to examine the presence of asymmetries for 18 OECD countries, including both oil importer and oil exporter but found a weak asymmetric effect of oil price changes in the sampled economies.

In fact, all the aforementioned studies provide mixed evidence. Hence, this paper adds to the existing literature by examining oil price pass-through into domestic prices between top oil-importing and oil-exporting countries in the world by using the TAR and MTAR models.

3. Data and Methodology

We focus our analysis on two groups of countries, namely the oil-importing and oil-exporting countries. The selection of countries is based on the availability of the data. From the World's Top Exports website–oil exports (http://www.worldstopexports.com/worlds-top-oil-exports-country/) and the oil-imports (http://www.worldstopexports.com/crude-oil-imports-by-country/), the top oil-importing countries chosen are China, United States, and Japan while for top oil-exporting countries, Saudi Arabia, Russia and Canada are chosen. We use quarterly data ranging from 1980:01 to 2017:02. The data consists of a CPI, PPI, global oil price, and industrial production index (IPI) or GDP. For consistency reason, all variables are converted into their natural logarithmic form.

In our research, we express CPI and PPI as a function in terms of other variables such as GDP and OIL. The general form of our model is as followed: Note that α is the constant, β_i are the coefficients of the variables in the form of their logarithm and u_t is the error term.

$$LCPI_t = \alpha + \beta_1 LPPI_t + \beta_2 LGDP_t + \beta_3 LOIL_t + \mu_t, \quad (1)$$

$$LPPI_t = \alpha + \beta_1 LCPI_t + \beta_2 LGDP_t + \beta_3 LOIL_t + \mu_t. \quad (2)$$

Note that α is the constant, β_i ($i = 1, 2, 3$) are the coefficients of the variables in their logarithms form and u_t is the error term.

First, unit root tests are performed on all the variables in logarithms to check on their stationarity properties and confirm with the integrated orders. Since all the variables are stationary integrated of I(1), we proceed with the checking on the long-run relation through symmetric and asymmetric cointegration tests. The linear cointegration tests such as Engle-Granger (EG) test by Engle and Granger (1987) and Phillips-Ouliaris (PO) cointegration test by Phillips and Ouliaris (1990) are conducted to test whether the residuals obtained from the cointegrating relationship (1 and 2) is stationary. This step is followed by the application of asymmetric cointegration test to check for the threshold cointegration and asymmetry. This test was developed by Enders and Granger (1998) and Enders and Siklos (2001) based on two models namely the threshold autoregressive (TAR) and momentum threshold autoregressive

(MTAR) models. The two main functions of these models are to capture the existence of a cointegrating relationship between oil price and domestic prices and if it exists, we further test if the relationship is asymmetric or symmetric.

When the long-run relationship is confirmed, we proceed to estimate the long-run relationship by conducting the Enders and Siklos (2001) (ES) cointegration test based on the following test equation:

$$\Delta u_t = \rho_1 I_t u_{t-1} + \rho_2 \left(1 - I_t\right) u_{t-1} + \sum_{i=1}^{k} \eta_i \Delta u_{t-i} + v_t , \tag{3}$$

where u_t indicates to the error term obtained from the long-run equation (1) and (2), I_t is the Heaviside indicator used to indicate the threshold levels and k is the optimal lag order to eliminate serial correlation of the error term.

In TAR model, we specify I_t to be a function of the error term in level as

$$I_t = \begin{cases} 1 & \text{if } u_{t-1} \geq t* \\ 0 & \text{if } u_{t-1} < t* \end{cases} \tag{4}$$

while for MTAR, I_t is a function of error term such that

$$I_t = \begin{cases} 1 & \text{if } \Delta u_{t-1} \geq t* \\ 0 & \text{if } \Delta u_{t-1} < t* \end{cases} \tag{5}$$

Note that t^* is the threshold value. In TAR model, Heaviside indicator is used to decide if the last period error term is positive or negative. On the other hand, in MTAR model, the error term is indicated in the changes of error term. Therefore, error term with higher momentum in one direction than other is very suitable to apply MTAR model. For both TAR and MTAR model, the sufficient condition to ensure the stationarity of u_t is when -2 < (ρ_1, ρ_2) < 0 (Ibrahim and Chancharoenchai (2014)). The hypotheses for both TAR and MTAR model are:

$$H_0 : \rho_1 = \rho_2 = 0 \text{ (no cointegration)}$$
$$H_1 : \rho_1 < 0 \text{ and } \rho_2 < 0 \text{ (cointegration)}$$

The hypotheses are performed by referring to the T-max statistics, with the tabulated critical values of T-max in Enders and Siklos (2001). The rejection of the null hypothesis leads to the conclusion of no long-run relationship. In this case, no further test is needed to test for asymmetric effect. The short-run relationship can be estimated by using ordinary least square (OLS) at first difference. However, if the null hypothesis of ES test is rejected, we then proceed to test for the null hypothesis of symmetric adjustment, where

$$H_0 : \rho_1 = \rho_2 \text{ (symmetric adjustment)}$$
$$H_1 : \rho_1 \neq \rho_2 \text{ (asymmetric adjustment)}$$

This can be tested by using the standard F-statistics. Again, we need to refer to the critical values as tabulated in Enders and Siklos (2001). We conclude that there is asymmetric adjustment if both of our null hypotheses are rejected. Once we confirm the existence of an asymmetric cointegration relationship, we provide the error correction model (ECM) specification as follows to represent the behaviour of domestic prices inflation.

Model I: No cointegration

$$\Delta CPI_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta CPI_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta PPI_{t-i} + \sum_{i=1}^{k} \alpha_{3i} \Delta GDP_{t-i} + \sum_{i=1}^{k} \alpha_{4i} \Delta OIL_{t-i} + v_t \tag{6}$$

$$\Delta PPI_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} \Delta PPI_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta CPI_{t-i} + \sum_{i=1}^{k} \beta_{3i} \Delta GDP_{t-i} + \sum_{i=1}^{k} \beta_{4i} \Delta OIL_{t-i} + v_t \tag{7}$$

Model II: Symmetric cointegration

$$\Delta CPI_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta CPI_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta PPI_{t-i} + \sum_{i=1}^{k} \alpha_{3i} \Delta GDP_{t-i} + \sum_{i=1}^{k} \alpha_{4i} \Delta OIL_{t-i} + \lambda u_{t-1} + v_t \tag{8}$$

$$\Delta PPI_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} \Delta PPI_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta CPI_{t-i} + \sum_{i=1}^{k} \beta_{3i} \Delta GDP_{t-i} + \sum_{i=1}^{k} \beta_{4i} \Delta OIL_{t-i} + \lambda u_{t-1} + v_t \tag{9}$$

Model III: Asymmetric cointegration

$$\begin{aligned}\Delta CPI_t = \alpha_0 &+ \sum_{i=1}^{k} \alpha_{1i} \Delta CPI_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta PPI_{t-i} + \sum_{i=1}^{k} \alpha_{3i} \Delta GDP_{t-i} \\ &+ \sum_{i=1}^{k} \alpha_{4i} \Delta OIL_{t-i} + \lambda_1 z^{+}_{t-1} + \lambda_2 z^{-}_{t-1} + v_t\end{aligned} \tag{10}$$

$$\begin{aligned}\Delta PPI_t = \beta_0 &+ \sum_{i=1}^{k} \beta_{1i} \Delta PPI_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta CPI_{t-i} + \sum_{i=1}^{k} \beta_{3i} \Delta GDP_{t-i} \\ &+ \sum_{i=1}^{k} \beta_{4i} \Delta OIL_{t-i} + \lambda_1 z^{+}_{t-1} + \lambda_2 z^{-}_{t-1} + v_t\end{aligned} \tag{11}$$

Note that Δ is the first difference operator, α_0 and β_0 are the constant terms, α_{ni} and β_{ni} are the coefficients *(n* = 1, 2, 3; *i* = 1, 2, …, *k*), *k* is the optimal lag orders, λ is the coefficient of error correction term (ECT) for symmetric cointegration model while λ_1 and λ_2 are the coefficients of ECT for asymmetric cointegration model which measures the speed at which the long-run disequilibrium is corrected in the next period, Z^{+}_{t-1} and Z^{-}_{t-1} are the asymmetric adjustments with $Z^{+}_{t-1} = I_t u_{t-1}$ and $Z^{-}_{t-1} = (1 - I_t) u_{t-1}$, u is the ECT representing the deviation of price level (PPI and CPI) from its long-run value and other variables are as defined above (1 and 2).

We adopt Model I when no cointegration can be detected. This means that the variables only possess a short-run relationship and the effect will disappear over time. In the case where there is symmetric cointegration between variables, Model II is applied and for asymmetric cointegration, Model III is the best to represent the behaviour of domestic prices inflation. Model II and III are useful in combining the short-run dynamics and long-run information in the data series. The error correction term shows how fast and in what direction the variables adjust to errors in the long-run equilibrium relationship. In model III, the finding $\lambda_1 \neq \lambda_2$ implies that the speed of adjustments to the long-run path are not equal across the two states of ECT.

At the same time, we also subject the models at each stage to residual diagnostic tests, namely LM and ARCH tests to show that our residual of estimations do not have autocorrelation and heteroskedasticity problems. Next, we apply the Wald test to check whether the accumulated short-run coefficient for a variable is statistically significant. Finally, for the models which capture the presence of symmetric and asymmetric cointegration, we use Stock and Watson (1993) dynamic ordinary least square (DOLS) approach to estimate the long-run relationship between oil price and domestic prices.

The Stock-Watson DOLS model is specified as follows:

$$\begin{aligned} CPI_t &= \alpha_0 + \alpha_1 PPI_t + \alpha_2 GDP_t + \alpha_3 OIL_t + \sum_{i=-k}^{k} \gamma_{1i} \Delta PPI_{t-i} \\ &\quad + \sum_{i=-k}^{k} \gamma_{2i} \Delta GDP_{t-i} + \sum_{i=-k}^{k} \gamma_{3i} \Delta OIL_{t-i} + u_t \end{aligned} \quad (12)$$

$$\begin{aligned} PPI_t &= \beta_0 + \beta_1 CPI_t + \beta_2 GDP_t + \beta_3 OIL_t + \sum_{i=-k}^{k} \delta_{1i} \Delta CPI_{t-i} \\ &\quad + \sum_{i=-k}^{k} \delta_{2i} \Delta GDP_{t-i} + \sum_{i=-k}^{k} \delta_{3i} \Delta OIL_{t-i} + u_t \end{aligned} \quad (13)$$

This method is good in coping with small sample and dynamic sources of bias. This single equation estimator also corrects for regressor endogeneity by the inclusion of leads and lags of the first differenced (I(1)) terms (Ibrahim & Chancharoenchai 2014).

4. Results and Discussions

Before conducting the estimation, we perform unit root test to check for the stationarity and the number of integrating order of the variables. We apply the tests of augmented Dickey-Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Phillips-Perron (PP). We use the notation *, ** and *** to indicate the significance level at 10%, 5%, and 1% respectively. The null hypothesis for both ADF and PP test is the series has no unit-root while the null hypothesis for KPSS is the series has no unit-root. Therefore, the rejection of the null hypothesis for ADF and PP indicates to the stationarity while that in KPSS indicates to non-stationary. The results are summarized in Table 1 (oil-importing countries) and Table 2 (oil-exporting countries). From the result obtained (Table 1 and 2), we conclude that all the variables in all countries show I(1).

Next, we perform the ES asymmetric cointegration test based on the TAR and MTAR models which is useful to check for the threshold cointegration and asymmetry. We conduct the test for two cases, which are (1) setting the threshold value to zero and (2) non-zero threshold value - use initial search for the potential threshold value that minimizes the sum of squared errors. From the results (Table 3 and 4), the null hypothesis of no cointegration cannot be rejected for all countries except for the case in Japan, namely LCPI_JPN. In the presence of cointegration, we further test for the null hypothesis of symmetric adjustment in the case of CPI in Japan while for other countries, no further test is needed due to no cointegration. The result is showed in Table 5 and the null hypothesis of symmetric adjustment cannot be rejected, implying that the cointegrating relationship in LCPI_JPN is symmetry.

Next, we proceed to the symmetric cointegration test. This step is to justify whether the results of the asymmetric cointegration test are consistent with the results of the symmetric cointegration test. To do this, we apply the Engle-Granger (EG) and Phillips-Ouliaris (PO) tests. The results of the EG and PO tests are summarized in Table 6 and 7. Our results show some evidence to reject the null of no cointegration for both the consumer price (LCPI) and producer price (LPPI) inflation in China, Japan, and Canada, indicating the existence of a long-run relationship in the consumer price and producer price inflation with the oil price and other variables. Combining the results of symmetric and asymmetric cointegration tests, Model I is used for both CPI and PPI in the United States, Saudi Arabia, and Russia (no cointegration) while Model II seems to be preferred for both CPI and PPI in China, Japan, and Canada (cointegration with symmetric adjustment).

Table 1: Unit-root tests – top oil-importing countries

Countries	Variable	ADF		KPSS		PP	
		Level	1st difference	Level	1st difference	Level	1st difference
United States	LCPI_US	-1.8699	-6.1765***	0.3697***	0.1157	-3.7211**	-9.3336***
	LPPI_US	-2.1220	-9.1964***	0.1142	0.0803	-2.7317	-8.5296***
	LGDP_US	-2.0785	-6.3053***	0.3408***	0.0438	-1.6098	-8.6519***
	LBRENT	-1.2396	-9.8039***	0.8715***	0.1275	-1.4187	-9.9717***
China	LCPI_CHN	-2.1666	-4.9563***	0.2467***	0.0996	-1.2871	-7.6990***
	LPPI_CHN	-5.2874***	-5.4572***	0.1308	0.1350	-3.6124***	-4.4996***
	LGDP_CHN	0.0379	-2.9933**	1.2019***	0.1084	-0.2993	-23.5937***
	LBRENT	-1.7154	-7.1510***	0.9285***	0.1577	-1.5539	-6.9953***
Japan	LCPI_JPN	-1.8185	-4.0493***	0.3417***	0.1729**	-3.6189**	-14.4294***
	LPPI_JPN	-2.3382	-9.2865***	0.9746***	0.0765	-1.4445	-9.2851***
	LGDP_JPN	-2.0723	-2.5953	0.3505***	0.1078	-3.5023**	-35.4225***
	LBRENT	-1.2396	-9.8039***	0.8715***	0.1275	-1.4187	-9.9717***

Table 2: Unit-root tests – top oil-exporting countries

Countries	Variable	ADF		KPSS		PP	
		Level	1st difference	Level	1st difference	Level	1st difference
Saudi Arabia	LCPI_SA	-0.8554	-7.9390***	0.2684***	0.1030	-1.0649	-8.1858***
	LPPI_SA	-2.8977	-8.4536***	0.1303*	0.1270*	-2.4550	-8.4536***
	LIPI_SA	-3.3744**	-3.8721***	0.9131***	0.2724	-4.0212***	-11.8119***
	LBRENT	-1.2141	-8.9395***	1.0899***	0.0968	-1.3054	-9.0100***
Russia	LCPI_RUS	-5.4657***	-4.5967***	0.2915***	0.1673**	-5.5631***	-3.3732*
	LPPI_RUS	-3.1342	-3.8221**	0.3243***	0.1302*	-5.4406***	-4.1597***
	LGDP_RUS	-1.0973	-4.9456***	0.3176***	0.1448*	-3.5464**	-12.0822***
	LBRENT	-1.6287	-7.4929***	1.0296***	0.1543	-1.5910	-7.3443***
Canada	LCPI_CAN	-2.3487	-3.7882***	1.4115***	0.9032***	-6.4532***	-6.2940***
	LPPI_CAN	-4.5239***	-8.5249***	0.2768***	0.0917	-4.1087***	-8.1180***
	LGDP_CAN	-1.9800	-6.1651***	0.2479***	0.0921	-4.6502***	-17.5015***
	LBRENT	-1.2396	-9.8039***	0.8715***	0.1275	-1.4187	-9.9717***

Table 3: Asymmetric cointegration test – top oil-importing countries

Countries	Variables	ES Test			
		TAR		MTAR	
		Threshold value = 0	Nonzero threshold value	Threshold value = 0	Nonzero threshold value
United States	LCPI_US	-1.6944	-1.5739	-0.7737	0.5124
	LPPI_US	-1.0402	-0.5426	-1.0796	1.0554
China	LCPI_CHN	-1.5249	-1.1307	-0.8916	0.6130
	LPPI_CHN	-2.3998	-2.5160	-2.4567	-2.5207
Japan	LCPI_JPN	-2.8860**	-2.7896**	-2.8412**	-1.9058
	LPPI_JPN	-1.3667	-1.0539	-1.2259	-1.8761

Table 4: Asymmetric cointegration test – top oil-exporting countries

Countries	Variables	ES Test			
		TAR		MTAR	
		Threshold value = 0	Nonzero threshold value	Threshold value = 0	Nonzero threshold value
Saudi Arabia	LCPI_SA	-1.4857	-1.8242	-1.5430	-1.3738
	LPPI_SA	-1.7455	-1.6105	-2.0194	-1.9487
Russia	LCPI_RUS	-1.8967	-1.4129	-1.4256	-0.5865
	LPPI_RUS	-2.5433	-2.6170	-2.1410	-2.1000
Canada	LCPI_CAN	-1.8616	-1.6191	-0.7930	-0.1574
	LPPI_CAN	-2.1351	-2.1438	-1.7194	0.2894

Table 5: Asymmetric adjustment – Japan

Variables	Asymmetry Test			
	TAR		MTAR	
	Threshold value = 0	Nonzero threshold value	Threshold value = 0	Nonzero threshold value
LCPI_JPN	0.1445	0.5623	0.1170	0.3472

Table 6: Symmetric cointegration test – top oil-importing countries

Countries	Variables	EG test		PO test	
		tau-statistic	*z*-statistic	*tau*-statistic	*z*-statistic
United States	LCPI_US	-2.5359	-14.0908	-3.2911	-18.8727
	LPPI_US	-2.2190	-10.8240	-2.1809	-10.4193
China	LCPI_CHN	-2.2207	-9.7693	-4.5300**	-31.1514**
	LPPI_CHN	-5.5529***	-63.5739***	-3.5834	-23.1067
Japan	LCPI_JPN	-3.6279	-35.1938**	-9.4985***	-122.6690***
	LPPI_JPN	-2.4833	-20.8506	-4.1776**	-27.4781*

Table 7: Symmetric cointegration test – top oil-exporting countries

Countries	Variables	EG test		PO test	
		tau-statistic	*z*-statistic	*tau*-statistic	*z*-statistic
Saudi Arabia	LCPI_SA	-1.9373	-8.1707	-2.0816	-9.2755
	LPPI_SA	-3.7585	-25.0638	-3.7821	-25.1957
Russia	LCPI_RUS	-3.3065	-23.0456	-2.8459	-15.3905
	LPPI_RUS	-3.9636*	-28.3284*	-3.4809	-19.7203
Canada	LCPI_CAN	-3.4921	-34.0009**	-3.2383	-17.7350
	LPPI_CAN	-3.4457	-251.4643***	-3.5013	-22.0705

4.1. ECM Equation and Long-Run Adjustment

We apply the general-to-specific procedure to trim insignificant first-differenced right-hand-side variables to generate our specification of the three models. The estimation results of Model I and II with the diagnostic statistics are summarized in Table 8 and 9. Overall, the performance of the models is satisfactory as reflected by the adjusted R^2 and significant F statistics. Furthermore, the models almost pass all the diagnostics tests with no autocorrelation and heteroskedasticity problems.

The increase in GDP has led to a higher CPI inflation in all top oil-importing countries but it leads to lower CPI inflation in Canada, the only top oil-exporting country which shows significant GDP pass-through effect. On the other hand, the increase in GDP is followed by a higher PPI inflation in all top oil-exporting countries except Saudi Arabia but it leads to a decrease in PPI inflation in all top oil-importing countries. The opposite relationship between the GDP and CPI inflation in Canada and also between the GDP and PPI inflation in all top oil-importing countries could be mainly explained by the successful role of monetary policy in achieving high economic growth with low inflation.

The higher oil price leads to higher domestic inflation in almost all the top oil-importers and exporters. However, the impact of oil price pass-through into PPI inflation is larger than CPI inflation. As oil is used as the main input in the production of many goods, higher oil price leads to higher cost of production and hence increase the PPI inflation. In Japan and Russia, an increase in oil price leads to a reduction in CPI inflation. This suggests that the monetary policy in those countries effectively lower the inflation against the higher oil price.

Moreover, higher PPI inflation leads to higher CPI inflation in both top oil-importing and exporting countries. This situation could be explained by cost-push inflation in theory. The changes in the prices of the raw materials are passed into producer prices. So, increase in the price of raw material such as oil price will increase the cost of production which in turn affect the prices of a variety of goods and services as a producer may pass the production costs to consumers. Hence, an increase in prices of producer goods would cause the PPI to rise and in turn, push up the consumer prices Clark (1995).

In addition, the higher CPI inflation also leads to higher PPI inflation in both top oil-importing and exporting countries. Such a phenomenon could be elucidated by the demand-pull inflation. The demand for final goods and services determines the demand for inputs used in production. So, the cost of production reflects the opportunity cost of resources and intermediate goods, which in turn reflects the demand for the final goods and services (Caporale *et al.* 2002). Therefore, this implies that consumer prices would affect producer prices.

Apart from that, we also document error-correction coefficients of the CPI and PPI equations which belong to model II. The error-correction coefficient measures the speed of adjustment to the long-run equilibrium path. With the presence of cointegration, we find the error-correction coefficients of the CPI equation in China (significant at 10% level) and Canada to be negative and significant. Between these two countries, China has a larger error-correction coefficient of the CPI equation. Hence, the CPI in China takes a shorter time to converge to its long-run equilibrium value relative to Canada. For the PPI equation, we observe the error-correction coefficients in Canada to be positive and significant. In the case of the CPI and PPI equations in Japan and also the PPI equation in China, the error-correction coefficients turn out to be insignificant.

By comparing among the top oil-importing countries, we find that Japan has the largest short-run oil price pass-through effect on both CPI and PPI inflation. We also observe that Japan has the largest short-run PPI pass-through effect on CPI inflation and the largest short-run CPI pass-through effect on the PPI inflation. Besides that, the United States has the largest short-run GDP pass-through effect on both CPI and PPI inflation. Among the top oil-exporting countries, we note that Russia has the largest short-run oil price and PPI pass-through effect into CPI inflation and the largest short-run oil price and CPI pass-through effect on PPI inflation. Besides that, Canada has the largest short-run pass-through of GDP on PPI inflation and also the only oil-exporting country which has significant short-run pass-through of GDP into CPI inflation.

Comparing the estimation results across top oil-importing and exporting countries, we observe that although oil price has significant pass-through effect on domestic inflation, its impact is relatively smaller than the other variables (GDP, CPI, and PPI). In top oil-importing countries, GDP and PPI appear to be the main determinants to CPI inflation whereas GDP and CPI appear to be the main determinants to PPI inflation. On the other hand, in top oil-exporting countries, the main determinant to CPI inflation is PPI inflation while the main determinants to PPI inflation are GDP and CPI inflation which are the same as the top oil-importing countries.

Table 8: Results of estimation – top oil-importing countries

Countries	Equation
United States	(a) Consumer Price
	$\Delta CPI_t = -\ 0.00007 + 0.1256\Delta CPI_{t-1} - 0.1495\Delta CPI_{t-2} + 0.1705\Delta CPI_{t-3} + 0.3969\Delta CPI_{t-4} + 0.3320\Delta PPI_t$
	(0.9038) (0.1032) (0.0444) (0.0250) (0.0000) (0.0000)
	$-\ 0.0424\Delta PPI_{t-1} + 0.0266\Delta PPI_{t-2} - 0.0609\Delta PPI_{t-3} - 0.1145\Delta PPI_{t-4} + 0.0752\Delta GDP_t$
	(0.2074) (0.4029) (0.0591) (0.0002) (0.0492)
	$-\ 0.1060\Delta GDP_{t-1} + 0.1040\Delta GDP_{t-2} + 0.1097\Delta GDP_{t-3} + 0.0011\Delta OIL_t$
	(0.0074) (0.0065) (0.0034) (0.6338)
	Adj-R^2 = 0.8452 F-stat = 57.1457 (0.000)
	(b) Producer Price
	$\Delta PPI_t = 0.0001 + 0.2425\Delta PPI_{t-1} - 0.0369\Delta PPI_{t-2} + 0.0925\Delta PPI_{t-3} + 0.1605\Delta PPI_{t-4} + 1.5563\Delta CPI_t$
	(0.9363) (0.0007) (0.5925) (0.1875) (0.0168) (0.0000)
	$-\ 0.2048\Delta CPI_{t-1} + 0.0498\Delta CPI_{t-2} - 0.1347\Delta CPI_{t-3} - 0.4953\Delta CPI_{t-4} - 0.0695\Delta GDP_t$
	(0.2206) (0.7589) (0.4174) (0.0020) (0.4045)
	$+\ 0.2065\Delta GDP_{t-1} - 0.1686\Delta GDP_{t-2} - 0.1686\Delta GDP_{t-3} + 0.0285\Delta OIL_t$
	(0.0163) (0.0429) (0.0390) (0.0000)
	Adj-R^2 = 0.8413 F-stat = 55.5254 (0.000)
China	(a) Consumer Price
	$\Delta CPI_t = -\ 0.0038 - 0.0513u_{t-1} + 0.2211\Delta CPI_{t-1} + 0.1007\Delta CPI_{t-2} - 0.0759\Delta CPI_{t-3} + 0.2487\Delta CPI_{t-4}$
	(0.0157) (0.0697) (0.0329) (0.2758) (0.4724) (0.0181)
	$+\ 0.0541\Delta PPI_t + 0.0024\Delta GDP_t + 0.0637\Delta GDP_{t-1} + 0.0342\Delta GDP_{t-2} + 0.0089\Delta OIL_t$
	(0.1751) (0.8298) (0.0000) (0.0067) (0.0881)
	Adj-R^2 = 0.7407 F-stat = 22.2965 (0.0000)
	(b) Producer Price
	$\Delta PPI_t = 0.0033 + 0.0254u_{t-1} + 0.4099\Delta PPI_{t-1} - 0.1264\Delta PPI_{t-2} + 0.1242\Delta PPI_{t-3} - 0.1884\Delta PPI_{t-4}$
	(0.4803) (0.6210) (0.0000) (0.2269) (0.2281) (0.0242)
	$+\ 0.2376\Delta CPI_t + 0.3268\Delta GDP_t - 0.0421\Delta GDP_{t-1} - 0.0400\Delta GDP_{t-2} - 0.0364\Delta GDP_{t-3}$
	(0.2934) (0.0021) (0.4234) (0.4050) (0.3852)
	$-\ 0.3608\Delta GDP_{t-4} + 0.0501\Delta OIL_t + 0.0112\Delta OIL_{t-1} + 0.0039\Delta OIL_{t-2} + 0.0053\Delta OIL_{t-3} - 0.0346\Delta OIL_{t-4}$
	(0.0003) (0.0000) (0.2995) (0.7218) (0.6131) (0.0008)
	Adj-R^2 = 0.7535 F-stat = 16.6648 (0.0000)
Japan	(a) Consumer Price
	$\Delta CPI_t = 0.0033 - 0.0277u_{t-1} - 0.0141\Delta CPI_{t-1} + 0.1602\Delta CPI_{t-2} + 0.2107\Delta CPI_{t-3} + 0.4189\Delta PPI_t$
	(0.0000) (0.2624) (0.8102) (0.0084) (0.0004) (0.0000)
	$+\ 0.0261\Delta GDP_t - 0.0261\Delta GDP_{t-1} + 0.0243\Delta GDP_{t-2} - 0.0057\Delta OIL_t - 0.0021\Delta OIL_{t-1}$
	(0.0000) (0.0002) (0.0001) (0.0072) (0.3013)
	$-\ 0.0021\Delta OIL_{t-2} - 0.0074\Delta OIL_{t-3}$
	(0.2855) (0.0001)
	Adj-R^2 = 0.7613 F-stat = 36.5732 (0.000)
	(b) Producer Price
	$\Delta PPI_t = -\ 0.0054 - 0.0606u_{t-1} + 0.1947\Delta PPI_{t-1} + 0.9650\Delta CPI_t - 0.0381\Delta GDP_t - 0.0068\Delta GDP_{t-1}$
	(0.0000) (0.1196) (0.0018) (0.0000) (0.0000) (0.5168)
	$-\ 0.0425\Delta GDP_{t-2} + 0.0215\Delta OIL_t + 0.0113\Delta OIL_{t-1} + 0.0057\Delta OIL_{t-2} + 0.0083\Delta OIL_{t-3}$
	(0.0000) (0.0000) (0.0005) (0.0571) (0.0047)
	Adj-R^2 = 0.7179 F-stat = 34.5442 (0.0000)

Table 9: Results of estimation – top oil-exporting countries

Countries	Equation
Saudi Arabia	(a) Consumer Price
	ΔCPI_t = - 0.0032 + 0.2911ΔCPI_{t-1} + 0.3121ΔPPI_t - 0.0032ΔIPI_t - 0.0062ΔOIL_t
	(0.0325) (0.0002) (0.0000) (0.7010) (0.1534)
	Adj-R^2 = 0.3695 F-stat = 15.5308 (0.000)
	(b) Producer Price
	ΔPPI_t = 0.0075+ 0.2408ΔPPI_{t-1} + 0.7967ΔCPI_t - 0.3652ΔCPI_{t-1} + 0.0143ΔIPI_t
	(0.0039) (0.0072) (0.0000) (0.0100) (0.3615)
	- 0.0107ΔIPI_{t-1} + 0.0013ΔIPI_{t-2} - 0.0093ΔIPI_{t-3} - 0.0268ΔIPI_{t-4} + 0.0183ΔOIL_t
	(0.4837) (0.9348) (0.4892) (0.0455) (0.0112)
	Adj-R^2 = 0.3392 F-stat = 7.2105 (0.000)
Russia	(a) Consumer Price
	ΔCPI_t = 0.0261 + 0.4141ΔCPI_{t-1} + 0.7217ΔPPI_t - 0.2887ΔPPI_{t-1} - 0.0374ΔGDP_t
	(0.0069) (0.0000) (0.0000) (0.0002) (0.2904)
	- 0.1486ΔOIL_t - 0.0003$TREND$
	(0.0000) (0.0298)
	Adj-R^2 = 0.8174 F-stat = 68.8862 (0.000)
	(b) Producer Price
	ΔPPI_t = - 0.0261+ 0.2169ΔPPI_{t-1} + 0.6239ΔCPI_t + 0.0924ΔGDP_t + 0.0686ΔGDP_{t-1}
	(0.0234) (0.0089) (0.0000) (0.0723) (0.1158)
	+ 0.0303ΔGDP_{t-2} + 0.1241ΔGDP_{t-3} + 0.1517ΔOIL_t + 0.0003$TREND$
	(0.4668) (0.0028) (0.0000) (0.0553)
	Adj-R^2 = 0.8548 F-stat = 66.5147 (0.000)
Canada	(a) Consumer Price
	ΔCPI_t = 0.0009 - 0.0304u_{t-1} + 0.3705ΔCPI_{t-1} + 0.0537ΔCPI_{t-2} + 0.1393ΔCPI_{t-3}
	(0.0894) (0.0057) (0.0000) (0.4529) (0.0519)
	+ 0.1805ΔCPI_{t-4} + 0.1973ΔPPI_t + 0.0063ΔGDP_t - 0.0426ΔGDP_{t-1}
	(0.0060) (0.0000) (0.5117) (0.0000)
	+ 0.0070ΔOIL_t
	(0.0059)
	Adj-R^2 = 0.6851 F-stat = 35.8154 (0.0000)
	(b) Producer Price
	ΔPPI_t = - 0.0026 + 0.0679u_{t-1} + 0.2583ΔPPI_{t-1} + 0.8965ΔCPI_t - 0.7358ΔCPI_{t-1}
	(0.0835) (0.0085) (0.0008) (0.0000) (0.0000)
	+ 0.0730ΔGDP_t + 0.1454ΔGDP_{t-1} + 0.0876ΔGDP_{t-2} + 0.1249ΔGDP_{t-3} + 0.0159ΔOIL_t
	(0.0544) (0.0001) (0.0154) (0.0006) (0.0053)
	Adj-R^2 = 0.4580 F-stat = 14.6117 (0.0000)

4.2. Long-run regression

Table 10-12 provide the estimated long-run coefficient for the model of consumer price and producer price inflation in China, Japan, and Canada respectively by using the DOLS estimation method since the long-run relationship is detected by cointegration tests. In the long run, an increase in GDP leads to higher CPI in both top oil-importing and exporting countries. We find that GDP elasticity for CPI is the largest in Canada (0.501) and lowest in Japan (0.162). In addition, Canada is the only country that has significant long-run pass-through of GDP into PPI (0.426). The large impact of GDP on CPI and PPI inflation in Canada can be indirectly explained by the oil price. The higher oil price will lead to higher output or income as Canada exports oil and thus resulting in higher consumption and price levels.

On the other hand, higher CPI inflation has led to higher PPI inflation in Japan but lower PPI inflation in China. We note that the long-run pass-through of CPI inflation into PPI inflation in Japan is higher than China and with a full pass-through rate (1.129), suggesting that an increase in CPI by 10% is expected to increase the PPI by 11.29%. On the other hand, China has significant negative long-run CPI inflation pass-through into PPI inflation (-0.348) at a 10% significance level which contradicts with our result in the short run which indicates insignificant CPI inflation pass-through into PPI inflation. Besides that, Japan is the only country that has significant long-run pass-through of PPI inflation into CPI inflation (0.419).

Turning to our main objective, we note that higher oil price tends to lower the CPI inflation in both top oil-importing and exporting countries, which are Japan and Canada respectively. We observe that Canada has higher negative long-run oil pass-through into CPI (-0.052) than Japan (-0.032). In Canada, the negative relationship between oil price and CPI contradicts the result obtained in the short run which shows a positive relationship. This could be mainly explained by an effective policy in controlling the price rigidity to achieve low inflation in the long run through energy subsidy. Such an energy subsidy can stabilize the energy price over time and hence the changes in oil prices do not have a significant impact on consumer prices. In Japan, the findings by Taghizadeh-Hesary and Yoshino (2015) suggests that the negative impact of crude oil price on CPI in Japan is due to the fact that aggregate supply in Japan is almost constant and hence, the demand side of the economy is mainly affected by higher energy price. Following the uncertain situation which occurred in Japan after the Fukushima Daiichi nuclear disaster, domestic consumption shrinks and results in price deflation in Japan. In addition, Japan is the only country that shows significant long-run oil price pass-through into PPI inflation (0.069).

Table 10: DOLS Estimation of Long-Run Relations – China

Dependent variables	Long-run coefficients					
	Constant	CPI_CHN	PPI_CHN	GDP_CHN	OIL	TREND
CPI_CHN	2.0939 [0.0002]	-	-0.0729 [0.3206]	0.2726 [0.0000]	0.0048 [0.6699]	-0.0079 [0.0000]
PPI_CHN	5.6747 [0.0000]	-0.3476 [0.0655]	-	0.0382 [0.3307]	0.0200 [0.2531]	-

Note: The numbers in squared brackets are *p*-values.

Table 11: DOLS Estimation of Long-Run Relations – Japan

Dependent variables	Long-run coefficients					
	Constant	CPI_JPN	PPI_JPN	GDP_JPN	OIL	TREND
CPI_JPN	-0.4175 [0.5305]	-	0.4190 [0.0000]	0.1623 [0.0009]	-0.0323 [0.0001]	0.0032 [0.0005]
PPI_JPN	-0.4822 [0.6891]	1.1285 [0.0000]	-	0.0041 [0.9654]	0.0691 [0.0000]	-0.0077 [0.0000]

Note: The numbers in squared brackets are *p* -values.

Table 12: DOLS Estimation of Long-Run Relations – Canada

Dependent variables	Long-run coefficients					
	Constant	CPI_CAN	PPI_CAN	GDP_CAN	OIL	TREND
CPI_CAN	-2.0694 [0.0000]	-	0.0905 [0.6572]	0.5011 [0.0000]	-0.0523 [0.0000]	-
PPI_CAN	-0.5822 [0.1159]	-0.0478 [0.8024]	-	0.4256 [0.0000]	-0.0161 [0.2068]	-

Note: The numbers in squared brackets are *p* -values.

5. Conclusion

The paper focuses on the impact of oil prices on domestic prices (CPI and PPI) for the selected top oil-importing and exporting countries by using symmetric and asymmetric cointegration and error-correction modelling approaches. The cointegration test result suggests the existence of a linear cointegration relationship in some of the top oil-importing (China and Japan) and exporting (Canada) countries. There is no nonlinear cointegration relationship in all the top oil-importing and exporting countries we examined.

Besides, our results show that oil price changes have a significant pass-through effect on domestic inflation in both the short-run and long-run. However, the oil price is not the main contributing factor to domestic inflation in both top oil-importing and exporting countries we examined. The impact of oil price on domestic prices is smaller than other factors such as GDP, PPI, and CPI. In the short run, higher oil price does lead to higher CPI inflation in almost all the oil-importing and exporting countries, but it leads to lower CPI inflation in the long run. Such circumstances could be explained by an effective policy in stabilizing the energy price through energy subsidy to achieve low inflation in the long-run and hence oil price changes do not have a significant impact on consumer prices. Across all the oil-importing and exporting countries, higher oil price leads to higher PPI in both short-run and long-run. As oil is used as the raw material in the production of many goods, higher oil price leads to higher cost of production and thus increases the PPI inflation.

In the top oil-importing countries, the main determinants of CPI inflation in both the short-run and long-run are GDP and PPI inflation. The main determinants of PPI inflation in the short-run are both GDP and CPI while in the long-run is only CPI. On the other hand, in the top oil-exporting countries, the main determinant of CPI inflation in the short run is PPI inflation while in the long run is GDP. The main determinants of PPI inflation in the short run are both GDP and CPI inflation while in the long run is only GDP.

In conclusion, GDP, CPI, PPI are highly linked as they are the main economic indicators. On the other hand, oil prices may affect the global economy with different impacts. The effect is determined by the oil dependency factor, with a higher impact in countries that are more oil-intensive. Also, the impact of oil is larger on PPI (at production level) than CPI (at consumer level) as the higher oil price is directly pass-through into production cost. Countries that are highly dependence on oil resources as production are more sensitive to oil price changes as oil prices may affect economic stability. Since monetary policy is suggested by many researchers as an important tool to mitigate economic fluctuations due to oil shocks and other influences, an effective monetary policy coexists with the fiscal policy could be implemented. The monetary policy through price control (targeting at low inflation) and fiscal policy through subsidies might reduce the shocks induced by oil price fluctuations and excess impact of macroeconomic factors on domestic prices to achieve stable economic growth.

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