Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

The nexus between asymmetric oil price fluctuations and inflation in Saudi Arabia: Evidence from a non-linear ARDL approach

Mustapha Ben Hassine [1, *], Mouldi Ben Amor [2]

[1]*Department of Economics, College of Business, Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia*
[2]*Department of Economics, Faculty of Economic Sciences and Management of Sousse, University of Sousse, Sousse, Tunisia*

ARTICLE INFO

Article history:
Received 12 December 2024
Received in revised form
27 April 2025
Accepted 3 July 2025

Keywords:
Oil price shocks
Inflation
Saudi Arabia
NARDL model
Asymmetric effects

ABSTRACT

This study examines the impact of oil price shocks on inflation in the Saudi Arabian economy using the Non-linear Autoregressive Distributed Lag (NARDL) approach with annual data from 1975 to 2021. The analysis separates oil price changes into positive and negative components to identify possible asymmetric effects on the consumer price index (CPI). The results reveal significant asymmetry in the relationship between oil prices and inflation in both the short run and the long run. In the short run, CPI increases more rapidly when oil prices fall, while it decreases more slowly when oil prices rise. The findings also show that money supply and the real output gap have a significant positive influence on inflation. These results provide important policy implications, suggesting that contractionary monetary policies are needed to control inflation. Moreover, policymakers should carefully consider oil price fluctuations, particularly during periods of falling oil prices when inflationary pressures may increase. This is especially relevant for Saudi Arabia, where the economy remains highly dependent on oil revenues to support essential public spending.

1. Introduction

Crude oil is the primary global energy source, and fluctuations in oil prices significantly impact inflation, primarily through their direct effect on price indices. Rising oil prices generally lead to increased inflation rates worldwide, emphasizing oil's critical role in economic activity and macroeconomic outcomes (Aliyev et al., 2023). Since the late 1980s, research has identified an asymmetric relationship between oil prices and economic performance, indicating that changes in oil prices have varying effects. Huntington (1998) and Hamilton (1983) discussed this asymmetrical relationship, noting that the costs associated with fluctuating oil prices can impede economic activity—lower prices typically enhance activity, while higher prices tend to suppress it. Berk and Yetkiner (2014) further supported this by demonstrating a significant negative impact of composite energy prices on gross domestic product (GDP) per capita and energy consumption.

Despite many developing countries experiencing currency depreciation and inflation, oil-exporting nations maintained low inflation rates until the early 2000s. Rising oil prices then contributed to inflation due to increased costs of imported goods. Notably, prices of goods and services often rise even when oil prices fall, but do not decrease during high oil price periods, indicating a non-linear relationship. The mid-1970s oil boom positively affected inflation, yet the effects of oil price changes are inconsistent. For example, inflation responded more sharply to the oil price increase in 2008 than to its decrease in 2006. In mid-2014, despite a significant drop in oil prices from $115 to $52 per barrel, inflation rose. Overall, the relationship between oil prices and inflation in oil-exporting countries is complex, as rising prices typically boost revenue and inflation, while falling prices can also lead to increased inflation (Agboola et al., 2024).

There is limited research examining the impact of oil prices on the Saudi Arabian consumer price index (CPI), particularly in relation to the output gap and its effect on long-term growth, using the New Keynesian Phillips Curve (NKPC) approach. Additionally, this study offers valuable insights into the monetary policy tools available to authorities for stabilizing economic activity amidst oil price

* Corresponding Author.
Email Address: benhassinemustapha@yahoo.fr (M. Ben Hassine)
https://doi.org/10.21833/ijaas.2025.08.003
Corresponding author's ORCID profile:
https://orcid.org/0000-0002-2267-9478

fluctuations. As compared to most of the previous literature that focused on this area and employed time series models for the Saudi Arabian case, this study evaluates the asymmetric influence of crude oil prices on the inflation rate in the Saudi Arabian economy. More precisely, this study attempts to evaluate whether a non-linear cointegration test with asymmetric adjustment towards a long-run equilibrium is sufficient to explain the long-run and short-run pass-through of crude oil to consumer prices in the Saudi Arabian economy. This study contributes to the existing literature in that it provides evidence of the partial pass-through of crude oil prices, in the long run, during periods of low and high fluctuating oil prices.

The remainder of this paper is organized as follows. Section 2 briefly reviews literature on oil price fluctuations and inflation. In Sections 3 and 4, we discuss the methodology and data used in our study. Section 5 discusses empirical findings. Finally, Section 6 concludes the study and provides policy implications.

2. Literature review

Research on the impact of oil prices on inflation has yielded mixed results. Many studies employ the Non-linear Autoregressive Distributed Lag (NARDL) model developed by Shin et al. (2014) to analyze the effects of both rising and falling oil prices. Hamilton (1983) has concentrated on the effects of oil prices on the US macroeconomy, establishing a strong connection between oil price increases and subsequent economic downturns. He posited that oil price shocks have significantly contributed to economic recessions in the United States following World War II.

Numerous studies on the relationship between oil price shocks and inflation have yielded inconsistent findings. Many researchers assumed a symmetric relationship, which often misrepresents reality. Hamilton (2003, 2011) advocated for non-linear modeling approaches as more appropriate. Lòpez-Villavicencio and Pourroy (2019) utilized state-space models and the NARDL approach, demonstrating that the pass-through from oil prices to inflation is significantly larger in inflation-targeting countries during oil price declines. Similarly, Pal and Mitra (2019) found significant short-run asymmetry in the impact of oil price changes on US inflation using a novel MTNARDL model, though no long-run asymmetry was observed.

In Algeria, Lacheheb and Sirag (2019) confirmed that the asymmetric effects between inflation and oil prices depend on whether prices are increasing or decreasing. Belloumi et al. (2023) explored how fluctuations in oil prices affect economic output and inflation in Saudi Arabia from 1980 to 2021. They found that increasing oil prices enhance long-term output growth, whereas decreasing prices have no impact. Additionally, both rising and falling oil prices affect inflation symmetrically: price increases result in higher inflation, while decreases lead to lower inflation. Moreover, a stronger Saudi currency may temporarily raise inflation. The study advises Saudi authorities to implement policies to address the inflationary impacts of oil price changes.

Lu et al. (2010) investigated the effects of oil price shocks on inflation in Taiwan from 1986 to 2008 using a bivariate GARCH approach. They found that direct effects of oil prices had a greater pass-through to inflation than indirect effects, with oil prices significantly Granger-causing inflation, and persistent volatility spillovers observed. Cunado and De Gracia (2005) studied the oil price-inflation relationship in six Asian countries—Japan, Singapore, South Korea, Malaysia, Thailand, and the Philippines—and confirmed asymmetries in this relationship, particularly when oil price shocks were measured in local currencies, although the impacts were primarily short-term and limited.

Bala and Chin (2018) employed an ARDL dynamic panel approach to analyze four African oil-producing countries (Algeria, Angola, Libya, and Nigeria), finding that both positive and negative oil price shocks increased inflation, with a more pronounced effect during price declines. Kelikume (2017) used a vector error correction model (VECM) to examine the impact of exchange rate and oil price shocks on inflation in Nigeria, revealing a 43% inflation increase from rising oil prices and a 29% increase from falling prices.

Razmi et al. (2016) studied the effects of oil price shocks on domestic prices in ASEAN-4 countries with a structural vector autoregressive (SVAR) model, finding that oil price increases raised the CPI in the Philippines and Thailand but decreased it in Indonesia, while having no significant effect in Malaysia.

Chou and Lin (2013) analyzed the oil price-inflation relationship in Taiwan using a non-linear error-correction model, confirming asymmetric relationships and indicating that oil prices have long-run effects on producer prices, with faster adjustments when prices significantly deviate from equilibrium.

Almalki et al. (2022) examined how structural oil shocks—specifically industrial production, world oil production, and spot crude oil prices—affect food prices in Saudi Arabia from 1986 to 2020. Using NARDL and SVAR models, they found that negative shocks in industrial production led to significant increases in food prices due to reduced economic activity and food shortages. Additionally, negative shocks in crude oil prices are linked to higher food prices, while increased oil supply generally lowers them. The study concluded that oil supply shocks are the main drivers of food price fluctuations, with oil demand shocks and crude oil prices also contributing significantly.

Li and Guo (2022) used a multiple threshold non-linear autoregressive distributed lag model (MTNARDL) to investigate the asymmetric effects of oil price shocks on inflation in BRICS countries from January 2000 to March 2021. They found significant asymmetries only in China, where inflation increased more sharply with decreasing oil prices. Ghosh and Kanjilal (2014) explored the inflation-oil price relationship in India using non-linear ARDL, revealing that negative oil price shocks had a greater impact on inflation than positive ones. Similarly, Ibrahim (2015) analyzed Malaysian data from 1971 to 2012 with non-linear ARDL, concluding that while long-run increases in oil prices significantly affected food prices, decreases did not have a comparable effect.

3. Theoretical model and econometric framework

3.1. Theoretical model

According to the price adjustment theoretical development of Calvo (1983), to analyze the association between macroeconomic variables, we undertake the New Keynesian Phillips Curve (NKPC) approach based on:

$$\pi_t = \alpha E_t \pi_{t+1} + \beta mc_t \quad (1)$$

where, subscript t denotes the time, π_t, $E_t\pi_{t+1}$ and mc_t are the current inflation rate, expected inflation rate, and production real marginal cost, respectively. Eq. 1 describes Michael's (2011) theoretical development of the optimal linear aggregate price adjustment for individual firms, where α and β are functions of the structural parameters, including the price adjustment probability.

According to Galı and Gertler (1999), when including lagged inflation in Eq. 1, and based on the insights of Rotemberg and Woodford (1999) as well as Bawa et al. (2016), it is assumed that labor market frictions are present but constant over time. Given that real marginal costs are a linear function of the output gap, Eq. 1 can be rewritten as follows:

$$\pi_t = \lambda_1 \pi_{t-1} + \lambda_2 m_{t-1} + \lambda_3 (y_t - y_t^*) \quad (2)$$

where, π_{t-1}, m_{t-1} and $(y_t - y_t^*)$ are the lagged inflation rate, lagged money supply growth, and the real output gap, respectively.

We adopted the approach used by Bawa et al. (2016), Bawa et al. (2020), and Bello and Sanusi (2019). Using the New Keynesian Phillips Curve (NKPC) methodology, Eq. 2 can be augmented by introducing the crude oil price to measure and analyze its effect on inflation in Saudi Arabia. Then the augmented Eq. 2 can be expressed as:

$$\pi_t = \lambda_0 + \lambda_1 \pi_{t-1} + \lambda_2 m_{t-1} + \lambda_3 (y_t - y_t^*) + \lambda_4 acop_t + \omega_t \quad (3)$$

where, at time t, $acop_t$ is the average crude oil price at time t, and ω_t is the error term. λ_i for $i = [0,4]$ are the model parameters to be estimated, where λ_0 is the intercept and the rest of the parameters set are associated with the explanatory variables included in Eq. 3.

3.2. Econometric framework

The econometric framework starts with the classic ARDL (p, q) model proposed by Pesaran and Pesaran (1997) and Pesaran et al. (2001), as follows:

$$\Im_t = \alpha + \mu t + \sum_{i=1}^{p} \gamma_i \Im_{t-i} + \sum_{i=0}^{q} \delta_i' X_{t-i} + \upsilon_t \quad (4)$$

where, $\Im_t$, is the dependent variable, X_{t-i} is the vector of explanatory variables, $[\alpha + \mu t]$ indicates the linear trend form, υ_t is an error term, and p and q are lag lengths selected automatically by the Schwarz Information Criterion (SIC).

To describe both long and short run dynamics, the unrestricted error correction model (UECM) is specified as follows:

$$\Delta\Im_t = \alpha + \mu t + \vartheta(\Im_{t-1} - \rho' X_t) + \sum_{i=1}^{p-1} \gamma_i^* \Delta\Im_{t-i} + \sum_{i=0}^{q-1} \delta_i^{*\prime} \Delta X_{t-i} + \upsilon_t \quad (5)$$

where, Δ is the first difference operator, and the parameters describing the long-run and short-run relationships are defined, respectively, as follows:

$$\vartheta = \sum_{i=1}^{p-1} \gamma_i - 1$$
$$\rho = \frac{\sum_{i=0}^{q} \delta_i}{1 - \sum_{i=1}^{p} \gamma_i}$$
$$\gamma_i^* = -\sum_{m=i+1}^{p} \gamma_m$$
$$\delta_i^* = -\sum_{m=i+1}^{q} \delta_m$$

$(\Im_{t-1} - \rho' X_t)$ traduced the error correction term that upholds the long-run relationship between the variables. We expected that ϑ as a speed of adjustment of inflation will be statistically significant and negative towards its long-run equilibrium state in case of any disturbance in the explanatory variables. The parameters γ_i^* and δ_i^* describe the short-run effects of the past inflation values and the explanatory variables on the current inflation values.

The goal of this study is to investigate both the short- and long-run relationships between the inflation rate and crude oil price asymmetric changes in Saudi Arabia. Therefore, we examine and analyze the asymmetric impact of oil prices on inflation using recent econometric approaches. To examine the inflation-oil asymmetric changes nexus, we use the non-linear ARDL model advocated by Shin et al. (2014) for the time series. The non-linear ARDL approach is considered an extension of the previous ARDL econometric technique developed by Pesaran et al. (2001).

Note that the natural logarithm of the real average crude oil price ($lacop_t$) is decomposed into positive ($lacop_t^+$) and negative ($lacop_t^-$) shocks to formulate a non-linear specification (Bawa et al., 2020) as follows:

$$lacop_t = lacop_0 + lacop_t^+ + lacop_t^- \quad (6)$$

where, $lacop_0$ is an intercept term, and $lacop_t^+$ and $lacop_t^-$ are the partial sums of the positive and negative changes in the oil price, respectively.

$$\begin{cases} lacop_t^+ = \sum_{i=1}^{t} \Delta lacop_i^+ = \sum_{i=1}^{t} max(\Delta lacop_i, 0) \\ lacop_t^- = \sum_{i=1}^{t} \Delta lacop_i^- = \sum_{i=1}^{t} min(\Delta lacop_i, 0) \end{cases} \quad (7)$$

From Eq. 5, we assume that the dependent variable ($\Im_t$) is denoted by ($lcpi_t$) as the natural logarithm of the CPI (2010=100). The vector X_t contains the explanatory variable set ($lm2_t, lacop_t, gap_t$), where $lm2_t$ is the natural logarithm of the broad money supply, $lacop_t$ is the natural logarithm of the real average crude oil price, and gap_t is gap pattern is computed on the difference in natural logarithm between GDP (real gross domestic product) and potential GDP. Thus, we use the default smoothing parameter ($\lambda = 100$ is retained because it is particularly standard for yearly data) proposed by Ravn and Uhlig (2002) to compute the real potential gross domestic product series according to the Hodrick and Prescott (1997) filter (HP). According to Shin et al. (2014) and from the previous equations set (Eqs. 5-7), we generate an estimable analytic form for NARDL as follows:

$$\Delta lcpi_t = \emptyset_{lcpi} lcpi_t + \emptyset_{lm2} lm2_t + \emptyset_{lacop}^{+} lacop_t^+ + \emptyset_{lacop}^{-} lacop_t^- + \emptyset_{gap} gap_t + \sum_{j=1}^{p-1} \gamma_{lcpi,j}\, \Delta lcpi_{t-j} + \sum_{k_1=1}^{q_1-1} \gamma_{lm2,k_1}\, \Delta lm2_{t-k_1} + \sum_{k_2=1}^{q_2-1} (\gamma_{lacop,k_2}^{+} \Delta lacop_{t-k_2}^{+} + \gamma_{lacop,k_2}^{-} \Delta lacop_{t-k_2}^{-}) + \sum_{k_3=1}^{q_3-1} \gamma_{gap,k_3}\, \Delta gap_{t-k_3} + \alpha + \mu t + \varepsilon_t \quad (8)$$

where, ε_t is an error term. Eq. 8 describes a NARDL (p, q_1, q_2, q_3) model where $lcpi$ leads an autoregressive process of order p, and $lm2$, asymmetric $lacop$, gap enter as distributed lag variables with orders q_1, q_2, q_3, respectively. The variables with (+) and (−) superscripts indicate the positive and negative partial sum decompositions of the underlying distributed lag variable, respectively. These partial sum decompositions explicitly model how asymmetries in the average crude oil price reflect Saudi Arabia's inflation in both the long and the short run.

4. Data and summary statistics

The aim of this study is to adopt a non-linear ARDL approach, such as that developed by Shin et al. (2014) for time series. Furthermore, we follow the approach used by Bawa et al. (2020) to investigate and analyze both short and long-run asymmetric reflection of oil price on inflation in the case of Saudi Arabia. The data used in this study are annual frequency over the period 1975-2021, taken in constant 2010 US dollars from the World Development Indicators in 2021 and from the World Bank Commodity Price data in 2021.

4.1. Data and preliminary analysis

All data used in this study were computed according to 2010 and set as the base year. Variable CPI is the consumer price index (2010=100). Thus, the index value for 2010 was 100. The broad money supply ($m2$) was measured in millions of US dollars. The average crude oil price (ACOP) is measured from Brent, Dubai, and WTI prices in constant 2010 US dollars. Tables 1 and 2 report the summary statistics for all variables of interest for econometric estimates. For econometric estimates purposes, Table 2 contains the log-natural transformation of observations of all interest variables defined in Table 1.

Table 1: Summary statistics for variables at the level

	RGDP	HPRGDP	M2	ACOP	CPI
Mean	4291.566	4279.553	151629.2	45.72456	84.31314
Median	3746.320	3632.870	59655.58	44.37861	76.69088
Maximum	7045.165	7181.172	549282.3	95.31152	126.2311
Minimum	2148.612	2774.553	6010.383	15.89910	46.65011
Standard deviation	1510.397	1469.453	165937.2	24.08624	19.94244
Skewness	0.605018	0.761765	1.124971	0.656107	0.815909
Kurtosis	2.105820	2.086493	2.759784	2.330617	2.454115
Jarque-Bera	4.433169	6.179799	10.02655	4.249541	5.798267
Probability	0.108981	0.045507	0.006649	0.119460	0.055071
Observations	47	47	47	47	47

RGDP is measured in billions of constant 2010 US dollars; Hodrick and Prescott (1997) filter applied on RGDP series (HPRGDP); Broad money supply (M2) is taken in millions of US dollars; The CPI is given as a percentage (2010=100); Average crude oil price is taken as a percentage in constant 2010 US dollars

Table 2: Summary statistics for variables computed by the natural logarithmic transformation

	LRGDP	LHPRGDP	LM2	LACOP	LCPI	GAP
Mean	8.305622	8.308551	11.29622	3.684436	4.409040	-0.002929
Median	8.228529	8.197778	10.99634	3.792758	4.339783	0.008212
Maximum	8.860097	8.879218	13.21637	4.557151	4.838115	0.225932
Minimum	7.672577	7.928245	8.701244	2.766263	3.842675	-0.281387
Standard deviation	0.345264	0.322328	1.182080	0.536999	0.224867	0.093586
Skewness	0.156661	0.521631	0.087101	0.046147	0.438621	-0.385772
Kurtosis	2.024865	1.781903	2.113595	1.721010	2.680384	4.414573
Jarque-Bera	2.054406	5.037141	1.598117	3.220154	1.707094	5.084419
Probability	0.358007	0.080575	0.449752	0.199872	0.425901	0.078692
Observations	47	47	47	47	47	47

LCPI: Log of consumer price index; LM2: Log of broad money supply; LACOP: Log of average crude oil price; GAP: Output gap, calculated as the log difference between actual and potential GDP; LRGDP: Log of real gross domestic product; LHPRGDP: Log of potential real GDP from HP filter

The authors' calculations used the log-natural transformation on observations of variables defined in Table 1. The variable denoted by GAP means pattern computing on the difference in natural logarithm between RGDP and potential (HPRGDP). Despite the great fluctuations in the price of oil, oil revenues continue to contribute to economic growth, as they provide very important financial resources. Fig. 1 displays global crude oil prices from 1975 to 2021. Since the mid-1980s, fluctuations in the price of oil have risen more frequently than previously, and OPEC has slightly lost the means to control global oil prices. In June 2014, the oil price level reached a maximum of US$115 per barrel, and around January 2016, the price dropped to less than US$40 per barrel due to increasing supply mostly by non-OPEC countries.

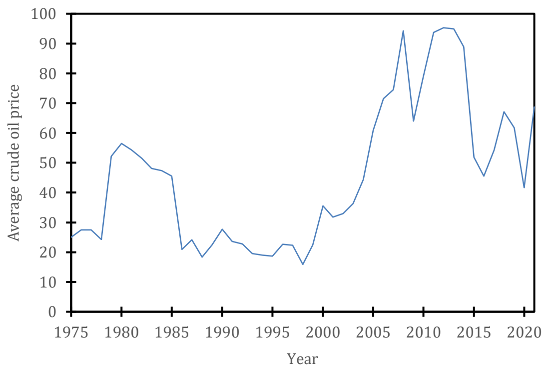


Fig. 1: The evolution of average crude oil price (ACOP) is taken as a percentage in constant 2010 US dollars

However, it appears that the money supply had a limited effect on the inflation rate in Saudi Arabia (Fig. 2). This is explained by the anchorage of the Saudi Riyal to the USD. We conclude that oil still has a very important indirect impact on the Saudi Arabian economy, and it will be transmitted through the monetary policy channel.

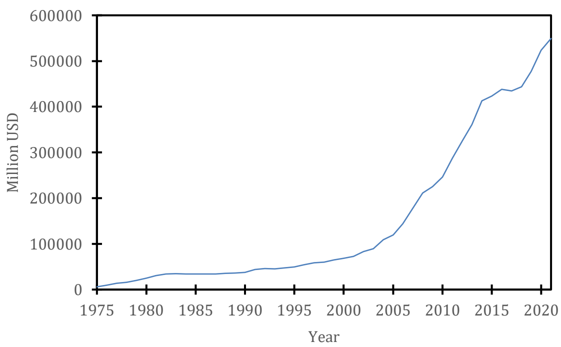


Fig. 2: Evolution of broad money supply (M2)

Fig. 3 illustrates the Saudi Arabian CPI evolution. It shows that CPI average grew by 2.3 percent during the last decade, despite a booming economic activity, in part contained by domestic subsidies/price cap and a strong US dollar.

Moreover, high oil revenues also encourage economic conditions that inhibit growth such as high inflation which constitutes a permanent challenge to most economies of the world, because of its undesirable effects on the activities of economic units and on economic growth rates (Fig. 4). Many studies have shown the importance of factors related to the outside world, especially the international prices of exports, in explaining the inflation rates in the Kingdom in the long and short terms (Ramady, 2009).

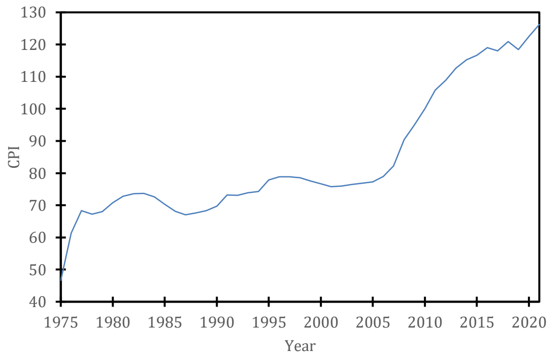


Fig. 3: Evolution in percentage of CPI (2010=100)

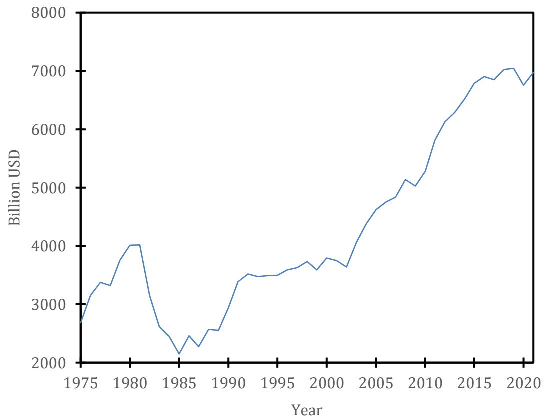


Fig. 4: Evolution of real gross domestic product (RGDP)

The surge in financial flows from oil revenues has enabled Saudi Arabia to achieve substantial growth over recent decades, but it has also contributed to rising inflation. Inflation peaked in 1975 after a significant correction in oil prices, then fell below zero in 1978 (Fig. 5). Throughout the 1980s and 1990s, inflation remained low, not exceeding 1%. However, starting in 2000, inflation began to rise, reaching around 9.8% in 2008 due to various internal and external factors, including increased reserve requirements by the central bank and a global rise in commodity prices linked to an oil boom. During 2011-2014, crude oil prices rose significantly, peaking at $107.7 per barrel, while inflation fluctuated, declining to 2.45% in 2018 and increasing again to 3.44% in 2020, coinciding with a drop in oil prices to $41.68 per barrel.

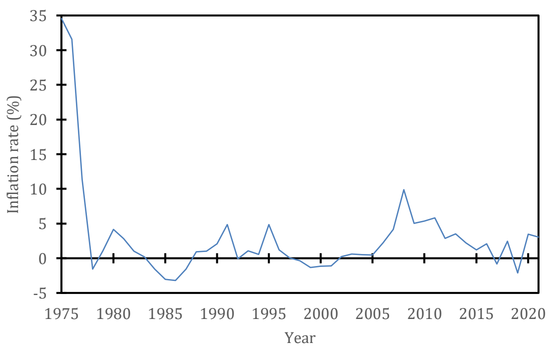


Fig. 5: Evolution in percentage of inflation rate

High inflation rates and the weakness of the US dollar present a dilemma for Saudi monetary authorities, particularly given the US Federal Reserve's successive interest rate cuts, which the Saudi Central Bank has not matched, contrary to expectations in a pegged exchange system. The growth spurred by oil revenue investment in development projects inevitably brings some inflation. There exists a strong connection between fluctuating oil prices and inflation in Saudi Arabia, as most of the government revenue is derived from oil sales. Additionally, the study includes Fig. 6, which illustrates the variables used in the empirical investigation.

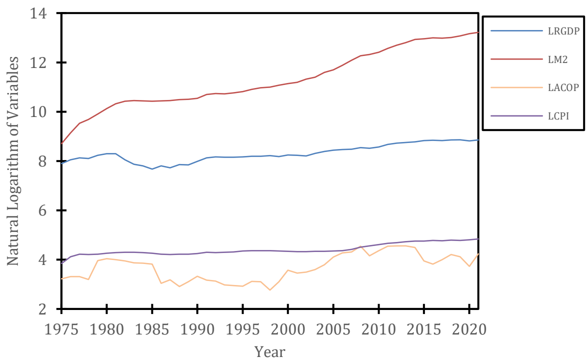


Fig. 6: Evolution log-natural transformation of interest variables

Therefore, understanding and controlling the root causes of inflation and investigating the impact of fluctuating oil prices on inflation in Saudi Arabia during the study period (1975-2021) became vital and very interesting because the rise in inflation rates raises serious concerns about the potential effects on economic stability and activity. This situation forces decision-makers to examine the relationship between oil price and inflation to maintain a climate of price stability and inflationary levels, as well as the nature of the economic policies that can be adopted to maintain economic development within the framework of an ambitious Vision 2030. The Saudi Arabian authority launched this program in 2016 to get out of oil dependence.

We remember that the output gap (GAP) is computed on the difference in natural logarithm between real GDP and potential real GDP estimated by the Hodrick and Prescott (1997) filter. The real GDP series is decomposed into a trend component (Trend) and a cyclical component (Cycle) reflecting cyclical fluctuations (Fig. 7). Fig. 8 plots both the evolution of LRGDP and LHPRGDP. It reveals that potential output increases (decreases) when effective output increases (decreases) permanently. However, the potential output will not be affected when the increase (decrease) in effective output is only temporary.

4.2. Stationarity tests

To examine the stationarity of the data, the panel unit root test (Im et al., 2003), the augmented Dickey–Fuller test (ADF) (Dickey and Fuller, 1979), and the Phillips–Perron test (Phillips and Perron, 1988) were applied. These tests assume an individual unit root process for each series. The results are presented in Tables 3 to 7. Based on the results of the three tests, the natural logarithm of the consumer price index (LCPI) and the natural logarithm of money supply (LM2) did not seem to be stationary at their level, but they were at first difference. Accordingly, they were integrated into order one I(1). On the other hand, all test results of the LACOP seem to be stationary at its level. Accordingly, it was integrated in the order of zero I(0). The bounds testing for cointegration should be suitable because no series contains more than one unit root, and consequently, NARDL could be applied.

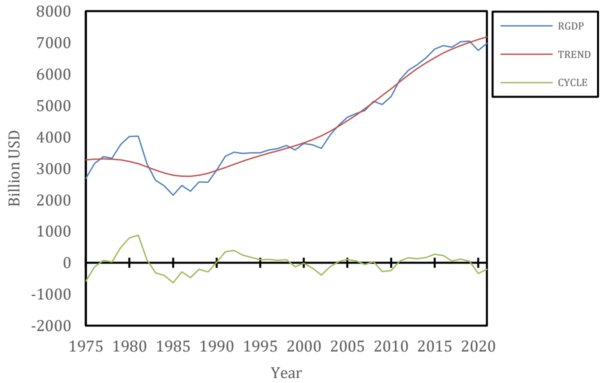


Fig. 7: Plot of the smoothing Hodrick and Prescott (1997) filter

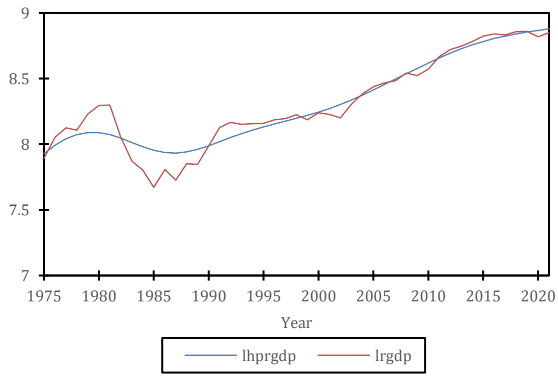


Fig. 8: Evolution of LRGDP and its potential values (LHPRGDP)

5. Econometric outcomes

While the previous analysis allows us to investigate the effect of oil prices on inflation, it implicitly assumes that the impact is symmetric. We avoid this assumption by decomposing the change in oil prices into their partial sum of positive and negative changes and estimating the non-linear version of the ARDL model as mentioned in Eq. 8.

5.1. ARDL bounds testing approach

Table 8 summarizes the results of several diagnostic tests. The Breusch–Godfrey Serial Correlation test (LM) yielded a p-value of 0.6118, well above the 0.1 threshold, indicating no evidence of serial correlation in the residuals. Similarly, the Jarque-Bera normality test (JB) produced a p-value of 0.6954, reinforcing the conclusion that the residuals are normally distributed. The autoregressive heteroskedasticity test (ARCH) also showed no signs of residuals' variance heterogeneity, with a p-value of 0.1405. Additionally, the computed Ramsey RESET statistic didn't reject the hypothesis of the correct functional form of Eq. 8, as indicated by a p-value of 0.1363. Furthermore, the bounds testing approach proposed by Pesaran et al. (2001) is applicable for models with mixed orders of integration, provided that none of the variables are I(2).

The calculated F-statistic rejected the null hypothesis of no cointegration—implying no long-run relationship among the model variables—at the 1% significance level. Overall, the results from these tests indicate that the model is free from classical regression issues and does not exhibit misspecification errors.

Table 3: Individual effects (intermediate ADF test)

Series	T-statistics	Probability	E(t)	E(var)	Lag	Panels	Observations
LCPI	-2.0900	0.2495	-1.523	0.788	1	9	47
LM2	-0.7730	0.8174	-1.523	0.788	1	9	47
LACOP	-1.5985	0.4754	-1.526	0.763	0	9	47
GAP	-3.3319	0.0189	-1.488	0.808	2	9	47

Null hypothesis: Unit root (individual unit root process); Method: IPS W-sat; Statistics: -0.97770; Probability: 0.1641 (probabilities are computed assuming asymptotic normality); Total (balanced) observations: 188

Table 4: Individual effects (intermediate ADF test)

Series	T-statistics	Probability	E(t)	E(var)	Lag	Panels	Observations
Δ(LCPI)	-3.0765	0.0353	-1.526	0.763	0	9	47
Δ(LM2)	-3.5689	0.0102	-1.526	0.763	0	9	47
Δ(LACOP)	-8.6375	0.0000	-1.526	0.763	0	9	47
Δ(GAP)	-7.5962	0.0000	-1.526	0.763	0	9	47

Δ denotes the first difference operator; Null hypothesis: Unit root (individual unit root process); Method: IPS W-sat; Statistics: -9.60271; Probability: 0.0000 (probabilities are computed assuming asymptotic normality); Total (balanced) observations: 188

Table 5: Individual effects, individual linear trends (intermediate ADF test)

Series	T-statistics	Probability	E(t)	E(var)	Lag	Panels	Observations
LCPI	-5.3740	0.0003	-2.179	0.664	1	9	47
LM2	-3.4307	0.0594	-2.179	0.664	1	9	47
LACOP	-2.0522	0.5582	-2.175	0.640	0	9	47
GAP	-3.2413	0.0890	-2.132	0.673	2	9	47

Null hypothesis: Unit root (individual unit root process); Method: IPS W-sat; Statistics: -3.34332; Probability: 0.0004 (probabilities are computed assuming asymptotic normality); Total (balanced) observations: 188

Table 6: Individual effects, individual linear trends (intermediate ADF test)

Series	T-statistics	Probability	E(t)	E(var)	Lag	Panels	Observations
Δ(LCPI)	-2.8405	0.1908	-2.175	0.640	0	9	47
Δ(LM2)	-3.2029	0.0963	-2.175	0.640	0	9	47
Δ(LACOP)	-8.4064	0.0000	-2.175	0.640	0	9	47
Δ(GAP)	-7.5615	0.0000	-2.175	0.640	0	9	47

Null hypothesis: Unit root (individual unit root process); Method: IPS W-sat; Statistics: -8.32188; Probability: 0.0000 (probabilities are computed assuming asymptotic normality); Total (balanced) observations: 188

Table 7: Time series unit root tests

	ADF		PP	
Level	**(I)**	**(II)**	**(I)**	**(II)**
LCPI	-2.090	-5.374***	-3.084**	-4.547***
LM2	-0.773	-3.431*	-2.335	-3.927**
LACOP	-1.599	-2.052	-1.574	-2.058
GAP	-3.332**	-3.241*	-3.478**	3.403*
First difference				
LCPI	-3.077**	-2.841	-4.495***	-3.531**
LM2	-3.569**	-3.203*	-4.285***	-3.506*
LACOP	-8.638***	-8.406***	-8.713***	-8.476***
GAP	-7.596***	-7.561***	-7.569***	-7.533***

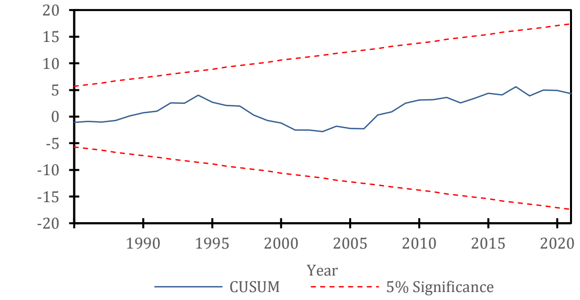
(I) and (II) indicate a model with only intercept and a model with intercept and deterministic time trend, respectively. ***, ** and * indicate the rejection of the null hypothesis at 1%, 5% and 10% significance levels, respectively

Figs. 9 and 10 illustrate, respectively, the representations of the cumulative sum (CUSUM) and squares (CUSUM of Squares) of recursive residuals. These demonstrate that the parameters were stable as the curves lie within the critical bounds of 5%. Therefore, the model is validated, and it is allowed to begin the cointegration analysis among variables with an appropriate NARDL approach.

Table 8: Diagnostic tests and F-test

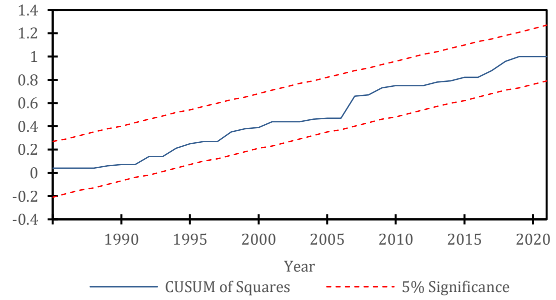
Type model	LM	JB	ARCH	RESET	F-statistic
NARDL model	0.4995	0.7265	2.2530	2.3391	6.7083***
	[0.6118]	[0.6954]	[0.1405]	[0.1363]	

The values in brackets indicate the p-values; For F-statistics of the difference model, the lower bound critical values are 3.03 (p-value < 0.1), 3.47 (p-value < 0.05) and 4.4 (p-value <0.01), and the upper bound critical values are 4.06 (p-value < 0.1), 4.57 (p-value < 0.05) and 5.72 (p-value < 0.01); ***: p-value < 0.01



The straight lines represent critical bounds at the p-value < 0.05

Fig. 9: Cumulative sum of recursive residuals



The straight lines represent critical bounds at the p-value < 0.05

Fig. 10: Cumulative sum of squares of recursive residuals

5.2. Short and long run estimates

The model written above, according to Eq. 8, is flexible enough to accommodate partial asymmetry, reflecting that the partial sums of the positive and negative changes in the oil price are asymmetric both among adjusting and cointegrating dynamics. To ensure the validated assumptions on asymmetry, we elaborate the following restrictions that will be formally tested:

$$\begin{cases} Short-run\ symmetry\ (H_0): \emptyset^-_{lacop} = \emptyset^+_{lacop} \\ Long-run\ symmetry\ (H_0): \sum_{k_2=1}^{q_2-1} \gamma^-_{lacop,k_2} = \sum_{k_2=1}^{q_2-1} \gamma^+_{lacop,k_2} \\ Long-run\ symmetry\ (H_0): \sum_{k_2=1}^{q_2-1} \gamma^-_{lacop,k_2} = \sum_{k_2=1}^{q_2-1} \gamma^+_{lacop,k_2}\ and\ \emptyset^-_{lacop} = \emptyset^+_{lacop} \end{cases} \quad (9)$$

Table 9 summarizes simple tests for long- and short-run symmetry, respectively, followed by the joint test for full symmetry. According to these results, we reject the null hypothesis of both the long-run and the joint symmetry test at the 1% significance level, and the short-run symmetry test for the partial sums of the positive and negative changes in the oil price at the 5% significance level. These findings allow us to use the model specified in Eq. 8 to implement the econometric estimates.

Table 9: Coefficient symmetry tests

	H_0: Short-run symmetry		H_0: Long-run symmetry		H_0: Joint short- and long- run symmetry	
Wald test	Statistic value	Probability	Statistic value	Probability	Statistic value	Probability
F-statistic	4.579558	0.0396	22.84062	0.0000	13.30445	0.0001
Chi-square	4.579558	0.0324	22.84062	0.0000	26.60890	0.0000

Table 10 displays the short-term results, where the coefficient error correction terms (ECT(−1)) had a negative and statistically significant value, indicating that any past shock was corrected within one year at a rate of 20%. It means that the Saudi Arabian economy's long-run equilibrium will be restored after about five years. The fact that the absolute value of the error correction term coefficients is between 0 and 1 allows that the relationships present a considerable potential predictability and that the spread movements are reverting.

In the short term, a rise (positive shock on the partial sum of the oil prices) and a fall (negative shock on the partial sum of the oil prices) in the oil prices decrease the inflation rate. The coefficient of LM2 was statistically significant. A 1% increase in LM2 leads to a 0.21% increase in the inflation rate.

The asymmetric effects of oil price fluctuations on inflation in Saudi Arabia were estimated, and the long-term results are shown in Table 11, demonstrating that the coefficient of the positive shock on the partial sum of oil prices (LACOP_POS) is statistically significant. An increase in oil prices increases the inflation rate. A decrease in oil prices (negative shock on the partial sum of oil prices) results in a decline in the inflation rate. The results confirm the asymmetric effect of positive and negative shocks on the partial sum of oil prices.

Table 10: Cointegrating form [ARDL(2, 1, 2, 1, 3), selected model]

Variable	Coefficient	T-statistics	Probability
Intercept	0.3332	5.8175	0.0000
Trend	-0.0170	-5.9213	0.0000
Δ(LCPI(-1))	0.2637	3.2446	0.0028
Δ(LM2)	0.2192	4.7416	0.0000
Δ(LACOP_POS)	-0.0198	-1.0719	0.2918
Δ(LACOP_POS (-1))	-0.0431	-3.4773	0.0015
Δ(LACOP_NEG)	-0.0430	-1.7692	0.0864
Δ(GAP)	0.0836	1.7224	0.0946
Δ(GAP (-1))	-0.1595	-3.4490	0.0016
Δ(GAP (-2))	-0.1070	-2.3352	0.0260
ECT(-1)	-0.2014	-6.1428	0.0000

Δ denotes the first difference operator. ECT indicates the error correction term; LACOP_POS: Partial sum of positive changes in log of average crude oil price; LACOP_NEG: Partial sum of negative changes in log of average crude oil price

Fig. 11 displays the cumulative dynamic multiplier for asymmetric oil price impact. It plots the response curves of their positive and negative variations. We assess the magnitude of the responses of the inflation rate to oil price increases and decreases that highlighting their asymmetrical effects on the inflation rate. It appears obvious that a positive shock to oil prices produces a significant 37% increase in the inflation rate in approximately 32 months, while a unit negative shock in oil prices exerts a significant decrease of 49% on inflation in roughly two years. Consequently, these empirical results provide some constructive policy implications for policymakers. Indeed, they should be cautious in implementing policies between the positive and negative changes in oil prices, mainly when oil prices increase.

Table 11: Estimated long-run coefficients

Variable	Coefficient	T-statistics	Probability
LM2	0.2977	2.0550	0.0481
LACOP_POS	0.3702	2.5471	0.0159
LACOP_NEG	-0.4918	-2.5539	0.0156
GAP	0.5041	2.3938	0.0227

ECT = LCPI - (0.2977*LM2 + 0.3702*LACOP_POS -0.4918*LACOP_NEG +0.5041*GAP); ECT indicates the error correction term

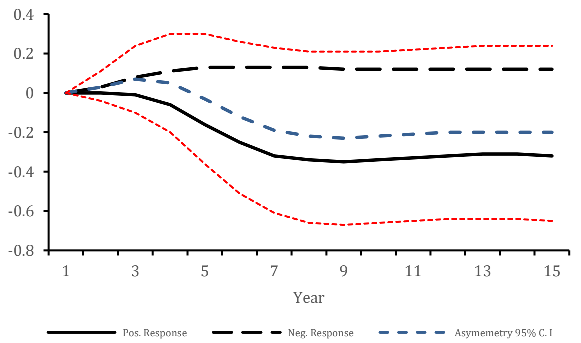


Fig. 11: Cumulative dynamic multiplier of oil price on inflation

6. Conclusion and policy implications

The study highlights the critical link between oil price variations and inflation in Saudi Arabia. Using annual data from the World Development Indicators and World Bank Commodity Price data, we prove empirically that changes in oil prices significantly influence inflation levels. Utilizing the NARDL model, the research distinguishes between positive and negative oil price shocks and their impact on the CPI. The findings indicate that a 1% increase in oil prices leads to a 0.37% rise in long-run inflation, while a 1% decrease in oil prices results in a 0.49% decline in inflation.

For Saudi Arabia, given the fixed exchange regime, an increase in the CPI moved with increasing oil prices. This is the case for an oil-dependent and less-diversified economy, which is vulnerable to positive or negative external shocks. A less diversified economy tends to import the most consumer and industrial goods from other countries to satisfy domestic demand. Therefore, changes in oil prices that affect the economies of foreign countries proportionally affect the Saudi Arabian economy as an oil-exporting country.

Policymakers must exercise caution when developing strategies to address the fluctuations in oil prices, as the economic implications can be complex and multifaceted. Notably, historical data indicate that inflation rates have frequently risen in response to declines in oil prices, challenging the conventional expectation that lower oil prices would alleviate inflationary pressures. This paradox suggests that other factors, such as supply chain disruptions, increased demand for goods, or shifts in consumer behavior, may play significant roles in influencing inflation during periods of falling oil prices. To tackle the inflationary challenges effectively, the implementation of contractionary monetary policies could be a viable strategy. By increasing interest rates and reducing the money supply, such policies can help curb excessive spending and investment, thereby stabilizing prices. However, policymakers should carefully consider the timing and magnitude of these measures, as overly aggressive approaches could stifle economic growth and lead to higher unemployment rates.

In addition to monetary policy adjustments, it is crucial for the government to implement extensive social awareness programs and encourage domestic food production, both in terms of quantity and quality. Enhancing domestic agricultural output can mitigate the effects of external shocks, such as global supply chain disruptions or volatile commodity prices. By investing in agricultural technologies, providing subsidies to local farmers, and promoting sustainable farming practices, the government can foster a more resilient food supply chain. This not only helps to stabilize food prices but also contributes to national food security, reducing dependency on imports and buffering the economy against global price fluctuations.

Overall, a comprehensive approach that combines prudent monetary policy with targeted support for domestic food production can create a more stable economic environment, mitigating the adverse effects of oil price volatility and fostering sustainable growth. This expansion elaborates on the complexities of oil price fluctuations, the role of monetary policy, and the importance of enhancing domestic food production to address inflation effectively.

List of abbreviations

ACOP	Average crude oil price
ADF	Augmented Dickey–Fuller test
ARDL	Autoregressive distributed lag
BRICS	Brazil, Russia, India, China, South Africa
CPI	Consumer price index
CUSUM	Cumulative sum
ECT	Error correction term
GDP	Gross domestic product
GARCH	Generalized autoregressive conditional heteroskedasticity
HP	Hodrick–Prescott filter
I(0)/I(1)	Integration order 0 / Integration order 1
IPS	Im, Pesaran, and Shin
JB	Jarque–Bera test
LM	Lagrange multiplier test
LT	Linear trend
MTNARDL	Multiple threshold non-linear

	autoregressive distributed lag
NARDL	Non-linear autoregressive distributed lag
NKPC	New Keynesian Phillips curve
OPEC	Organization of the Petroleum Exporting Countries
PP	Phillips–Perron test
RGDP	Real gross domestic product
RESET	Regression specification error test
SIC	Schwarz information criterion
SVAR	Structural vector autoregression
VECM	Vector error correction model
WTI	West Texas Intermediate crude oil
LCPI	Log of consumer price index
LM2	Log of broad money supply
LACOP	Log of average crude oil price
GAP	Output gap, calculated as the log difference between actual and potential GDP
LRGDP	Log of real gross domestic product
LHPRGDP	Log of potential real GDP from HP filter
LACOP_POS	Partial sum of positive changes in log of average crude oil price
LACOP_NEG	Partial sum of negative changes in log of average crude oil price

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Agboola E, Chowdhury R, and Yang B (2024). Oil price fluctuations and their impact on oil-exporting emerging economies. Economic Modelling, 132: 106665. https://doi.org/10.1016/j.econmod.2024.106665

Aliyev K, Humbatova S, and Gadim-Oglu NH (2023). How oil price changes affect inflation in an oil-exporting country: Evidence from Azerbaijan. Sustainability, 15(7): 5846. https://doi.org/10.3390/su15075846

Almalki AM, Hassan MU, and Amin MFB (2022). The asymmetric relationship between structural oil shocks and food prices: Evidence from Saudi Arabia. Applied Economics, 54(54): 6216-6233. https://doi.org/10.1080/00036846.2022.2083065

Bala U and Chin L (2018). Asymmetric impacts of oil price on inflation: An empirical study of African OPEC member countries. Energies, 11(11): 3017. https://doi.org/10.3390/en11113017

Bawa S, Abdullahi IS, and Ibrahim A (2016). Analysis of inflation dynamics in Nigeria (1981-2015). CBN Journal of Applied Statistics, 7(1): 255-276.

Bawa S, Abdullahi IS, Tukur DS, Barda SI, and Adams YJ (2020). Asymmetric impact of oil price on inflation in Nigeria. CBN Journal of Applied Statistics, 12(1): 85-113. https://doi.org/10.33429/Cjas.11220.4/8

Bello UA and Sanusi AR (2019). Inflation dynamics and exchange rate pass-through in Nigeria: Evidence from augmented nonlinear new Keynesian Philips curve. CBN Journal of Applied Statistics, 10(2): 109-138. https://doi.org/10.33429/Cjas.10219.4/6

Belloumi M, Aljazea A, and Alshehry A (2023). Study of the impact of crude oil prices on economic output and inflation in Saudi Arabia. Resources Policy, 86(A): 104179. https://doi.org/10.1016/j.resourpol.2023.104179

Berk Ý and Yetkiner H (2014). Energy prices and economic growth in the long run: Theory and evidence. Renewable and Sustainable Energy Reviews, 36: 228-235. https://doi.org/10.1016/j.rser.2014.04.051

Calvo GA (1983). Staggered prices in a utility-maximizing framework. Journal of Monetary Economics, 12(3): 383-398. https://doi.org/10.1016/0304-3932(83)90060-0

Chou KW and Lin PC (2013). Oil price shocks and producer prices in Taiwan: An application of non-linear error-correction models. Journal of Chinese Economic and Business Studies, 11(1): 59-72. https://doi.org/10.1080/14765284.2012.755302

Cunado J and De Gracia FP (2005). Oil prices, economic activity and inflation: Evidence for some Asian countries. The Quarterly Review of Economics and Finance, 45(1): 65-83. https://doi.org/10.1016/j.qref.2004.02.003

Dickey DA and Fuller WA (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a): 427-431. https://doi.org/10.1080/01621459.1979.10482531

Galı J and Gertler M (1999). Inflation dynamics: A structural econometric analysis. Journal of Monetary Economics, 44(2): 195-222. https://doi.org/10.1016/S0304-3932(99)00023-9

Ghosh S and Kanjilal K (2014). Oil price shocks on Indian economy: Evidence from Toda Yamamoto and Markov regime-switching VAR. Macroeconomics and Finance in Emerging Market Economies, 7(1): 122-139. https://doi.org/10.1080/17520843.2013.856333

Hamilton JD (1983). Oil and the macroeconomy since World War II. Journal of Political Economy, 91(2): 228-248. https://doi.org/10.1086/261140

Hamilton JD (2003). What is an oil shock? Journal of Econometrics, 113(2): 363-398. https://doi.org/10.1016/S0304-4076(02)00207-5

Hamilton JD (2011). Nonlinearities and the macroeconomic effects of oil prices. Macroeconomic Dynamics, 15(S3): 364-378. https://doi.org/10.1017/S1365100511000307

Hodrick RJ and Prescott EC (1997). Postwar US business cycles: An empirical investigation. Journal of Money, Credit, and Banking, 29(1): 1-16. https://doi.org/10.2307/2953682

Huntington HG (1998). Crude oil prices and US economic performance: Where does the asymmetry reside? The Energy Journal, 19(4): 107-132. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol19-No4-5

Ibrahim MH (2015). Oil and food prices in Malaysia: A nonlinear ARDL analysis. Agricultural and Food Economics, 3: 2. https://doi.org/10.1186/s40100-014-0020-3

Im KS, Pesaran MH, and Shin Y (2003). Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115(1): 53-74. https://doi.org/10.1016/S0304-4076(03)00092-7

Kelikume I (2017). Do exchange rate and oil price shocks have asymmetric effect on inflation? Some evidence from Nigeria. The Journal of Developing Areas, 51(4): 271-283. https://doi.org/10.1353/jda.2017.0101

Lacheheb M and Sirag A (2019). Oil price and inflation in Algeria: A nonlinear ARDL approach. The Quarterly Review of Economics and Finance, 73: 217-222. https://doi.org/10.1016/j.qref.2018.12.003

Li Y and Guo J (2022). The asymmetric impacts of oil price and shocks on inflation in BRICS: A multiple threshold nonlinear ARDL model. Applied Economics, 54(12): 1377-1395. https://doi.org/10.1080/00036846.2021.1976386

Lòpez-Villavicencio A and Pourroy M (2019). Inflation target and (a)symmetries in the oil price pass-through to inflation. Energy Economics, 80: 860-875. https://doi.org/10.1016/j.eneco.2019.01.025

Lu WC, Liu TK, and Tseng CY (2010). Volatility transmissions between shocks to the oil price and inflation: Evidence from a bivariate GARCH approach. Journal of Information and Optimization Sciences, 31(4): 927-939. https://doi.org/10.1080/02522667.2010.10700003

Michael W (2011). Interest and prices: Foundations of a theory of monetary policy. Princeton University Press, Princeton, USA.

Pal D and Mitra SK (2019). Asymmetric oil price transmission to the purchasing power of the US dollar: A multiple threshold NARDL modelling approach. Resources Policy, 64: 101508. https://doi.org/10.1016/j.resourpol.2019.101508

Pesaran MH and Pesaran B (1997). Microfit 4.0: Interactive econometric analysis. Oxford University Press, Oxford, UK.

Pesaran MH, Shin Y, and Smith RJ (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3): 289-326. https://doi.org/10.1002/jae.616

Phillips PC and Perron P (1988). Testing for a unit root in time series regression. Biometrika, 75(2): 335-346. https://doi.org/10.1093/biomet/75.2.335

Ramady MA (2009). External and internal determinants of inflation: A case of Saudi Arabia. Middle East Journal of Economics and Finance, 2(1-2): 25-38.

Ravn MO and Uhlig H (2002). On adjusting the Hodrick-Prescott filter for the frequency of observations. Review of Economics and Statistics, 84(2): 371-376. https://doi.org/10.1162/003465302317411604

Razmi F, Azali M, Chin L, and Habibullah MS (2016). The role of monetary transmission channels in transmitting oil price shocks to prices in ASEAN-4 countries during pre-and post-global financial crisis. Energy, 101: 581-591. https://doi.org/10.1016/j.energy.2016.02.036

Rotemberg JJ and Woodford M (1999). The cyclical behavior of prices and costs. Handbook of Macroeconomics, 1: 1051-1135. https://doi.org/10.3386/w6909

Shin Y, Yu B, and Greenwood-Nimmo M (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Sickles R and Horrace W (Eds.), Festschrift in honor of Peter Schmidt: Econometric methods and applications: 281-314. Springer, New York, USA. https://doi.org/10.1007/978-1-4899-8008-3_9