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Asymmetric impacts of oil prices on inflation in Egypt: A nonlinear ARDL approach

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Abstract

Unlike many studies that have adopted a linear approach to determine the effects of oil price changes on inflation, the present study applies a nonlinear approach to explore the asymmetric inflationary effects of positive and negative changes in oil prices. Although the results of linear autoregressive distributive lag model (ARDL) was inconclusive in detection the existence of co-integration, the results of the nonlinear ARDL model, which considers the asymmetric relationship between variables, confirmed the existence of co-integration which means that there is a long-run equilibrium relationship between inflation, oil prices, GDP, and money supply, in the Egyptian economy during the period 1960-2017. Results also captured short-run and long-run asymmetric impacts of oil price increases and decreases on inflation. These results impose challenges that minimize the ability of the Central Bank of Egypt in controlling inflation rates in the short-run because changes in oil prices, which positively affecting inflation, are determined globally and outside the effective area of domestic monetary policy.

الآثار غير المتماثلة لأسعار النفط على التضخم في مصر: تطبيق منهجية ARDL غير الخطية

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ملخص

على خلاف العديد من الدراسات التي استخدمت المنهج الخطي في تحديد تأثير التغيرات في أسعار النفط على التضخم، تطبق هذه الدراسة نموذجاً غير خطي لاستكشاف الآثار التضخمية غير المتماثلة لارتفاع وانخفاض أسعار النفط في مصر. وعلى الرغم من أن نتائج تطبيق نموذج الانحدار الذاتي الخطي لفترات الابطاء الموزعة جاءت غير حاسمة في تأكيد أو نفي وجود تكامل مشترك فيما بين المتغيرات، إلا أن نتائج تطبيق النموذج غير الخطي أكدت على وجود تكامل مشترك فيما بين المتغيرات، بما يعني علاقة توازنية طويلة الأجل بين التضخم وأسعار النفط والناتج المحلي الاجمالي وعرض النقود في الاقتصاد المصري خلال الفترة (1960-2017)، وأن أثر التغير في أسعار النفط على التضخم هو أثر غير متماثل في الأجلين القصير والطويل. وتفرض هذه النتائج تحديات على البنك المركزي المصري تقلل من قدرته على التحكم في معدلات التضخم في الأجل القصير لأن تغيرات أسعار النفط التي تؤثر على معدلات التضخم في الأجل القصير بشكل غير متماثل تتحدد عالمياً وبعيدة عن نطاق تأثير السياسة النقدية المحلية.

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1. Introduction

Oil plays an important role in the global economy, in both importing and exporting economies alike. It is a necessary input in production, as it represents a significant component in the export revenues for many countries or in imports bill for others, which means that any changes in its prices will be reflected, in some way, in economic growth as well as inflation rates in those economies (Chen et. al., 2020; Nasir et al., 2018). In this context, an important question arises about the nature of the impact of changes in oil prices on many of the macroeconomic indicators, especially the inflation rate, as many studies have assumed symmetric or linear effect of both the rise and the fall in oil prices on inflation rates, and therefore, despite the marked fluctuations in oil prices during the previous decades, the relationship between these two variables has been studied by many researchers in a linear rather than nonlinear framework (e.g. Álvarez et al., 2011; Cavalcanti & Jalles, 2013; Wu & Ni, 2011).

The symmetrical hypothesis of the inflationary effects of both positive and negative changes in oil prices in many studies has made the reliability of the results of these studies under question by many scholars (e.g. Lacheheb & Sirag, 2019; Salisu et al., 2017), especially after the advanced developments in econometric methods by the works of (Schorderet, 2003; Shin et al., 2014), which allow separation and distinguishing between the effect of positive and negative changes in one or all of the independent variables in the estimation models. These developments stimulated many empirical studies to analyze the relationships between the various economic variables in a non-linear framework that takes into account the potential asymmetric effects of the independent variable(s) when formulating the estimation models, especially when the independent variables include variables characterized by the fluctuation of their values over time like oil prices (e.g. Baz et al., 2019; Liang et al., 2019; Salisu et al., 2017; Ullah et al., 2020).

Despite a large number of studies that deal with the asymmetric relationship of the impact of oil price fluctuations on inflation in many developed and emerging economies employing both the time-series and panel data techniques, however, this relationship in the Egyptian economy is almost unexplored in an asymmetric framework in the empirical literature. This research gap in the Egyptian context may lead to the inability of monetary policy to capture the various inflationary effects of oil price changes in the short and long-runs, since assuming that the relationship between these two variables is linear, may deprive the monetary policy from important information, if the actual relationship between these two variables is asymmetric or nonlinear. This means that monetary policy will receive misleading signals that may affect its ability to control inflation rates in the Egyptian economy if the potential asymmetric inflationary effects of oil price fluctuations are neglected in the econometric techniques employed in estimating the relationship between these two variables. So, this study contributes to bridging the empirical research gap of the relationship between inflation and oil prices in the Egyptian economy by analyzing the asymmetric effects of oil price fluctuations on inflation rates in Egypt during a relatively long period of time (1960-2017).

There are many reasons why a re-examination of the relationship between changes in oil prices and inflation in Egypt is an important issue. First, Inflation has become a major problem in the Egyptian economy in recent years. After long years of low and moderate inflation rates ranging from 3% to less than 9% during the 1990s and the first half of 2000s, Egypt had suffered heavily from high inflation rates, influenced by a sharp rise in the world commodity prices; food and energy (oil prices), during the second half of 2000s (De Gregorio, 2012). Inflation in Egypt had been responded to these shocks and reached double-digit numbers, moreover, the consumer price index began to rise as a result of the political instability after 2011. These developments impose more analysis to estimate the inflationary impacts of oil price changes.

Second, in late 2016 Egypt reached an agreement with the International Monetary Fund (IMF) to implement economic reform policies which have reflected in more inflation. According to the data published by the Central Agency for Public Mobilization and Statistics, the annual headline consumer price index picked up by 29.8 percent in fiscal year 2016/2017, compared with only 14 percent a year earlier. This sharp rise in inflation rate was attributed to the strictly procedures undertaken by the government under the economic reform program policies approved by the IMF, particularly liberalizing the exchange rate of the Egyptian Pound, enforcing the Value Added Tax (VAT) Law, and rising fuel and electricity prices within the framework of reforming and restructuring the subsidy system, CBE (2018). These developments also have an impact on domestic energy prices including oil prices, and therefore it is necessary to estimate the inflationary impacts oil price changes in Egypt.

Third, in light of the Egyptian government's policy of gradually reducing the volume of fuel subsidies as a seriously steps to completely eliminate subsidies and leaving oil prices automatically determined according to market forces, it is important to know how this policy affects inflation rates in Egypt, especially, the trade account data reveal that Egypt has become a net importer country of petroleum in the recent years, its total imports of fuel, mineral oils and products amounted 8.78 billion U.S. dollars during the fiscal year 2016/2017 compared with only 4.82 billion dollars for oil exports during the same year, CBE (2018). This means that Egypt is suffering from a deficit in its oil transactions with the outside world of about 4 billion dollars. This deficit, which compared with 3.6 billion dollars in the previous year have inflationary effects in the Egyptian economy.

This study attempts to estimate the relationship between inflation and oil price changes in an asymmetric framework, which was not previously employed in empirical studies related to the Egyptian economy. The study applies the nonlinear autoregressive distributed lags approach (NARDL) developed by (Shin et al., 2014) as an extension of the well-known and widely used linear ARDL model of Pesaran et al., (2001). The NARDL model enables us to distinguish between the impact of the rise and the impact of the fall in oil prices on inflation in Egypt during the period (1960-2017).

Our findings indicate that the results extracted from the linear ARDL failed to confirm or reject co-integration among inflation and the independent variables in the estimated model, which, on the contrary, has been confirmed in the results of the NARDL model. The NARDL results confirmed also the asymmetrical relationship between inflation and oil prices in both short and long-runs. So, the main finding of this study is that it is not accurate to estimate the effect of oil price changes on inflation in Egypt in a symmetrical (linear) framework assumption, but it is necessary to do so in an asymmetric framework as a general approach in formulating the econometric model to analyze the relationship between these two variables.

The study is organized as follows: section 2 is devoted to a brief survey of the empirical studies on the relationship between inflation and oil prices, while section 3 focuses on explaining the methodology and data description of the variables used in the NARDL model. Section 4 curries out the empirical analysis of both ARDL and NARDL models and discusses the results, while section 5 concludes.

2. Related Literature

The relationship between inflation and changes in oil prices, for both importers and exporters economies, has witnessed a considerable concern in economic literature (e.g. Ahmadov et al., 2018; H. Berument & Taşçı, 2002; Bhattacharya & Bhattacharyya, 2001; Cerra, 2019; Chen, 2009; Cheng & Cao, 2019; Choi et al., 2018; Cologni & Manera, 2008; Cunado & De Gracia, 2005;

Cuñado & de Gracia, 2003; Darby, 1982; Hamilton, 1996; Istiak & Alam, 2019; Lacheheb & Sirag, 2019; Lardic & Mignon, 2008; Lin & Wu, 2012; López-Villavicencio & Pourroy, 2019; Mirdala, 2014; Nazlioglu et al., 2019; O'Neill et al., 2008; Roeger, 2005; Wu & Ni, 2011). Oil prices increases have a direct effect on output and then will influence the inflation rate indirectly (Barsky & Kilian, 2004). When oil price increases, the production costs also increase, and so the general price level.

López-Villavicencio & Pourroy (2019) applied state-space models to investigate the pass-through of oil price changes to consumer prices. Their large sample which contained 49 advanced and emerging economies and covering the period from 1970 to 2017, included two main groups, inflation targeting countries (IT) and non-inflation targeting countries (non-IT). They used a dynamic GMM in formulating the pass-through relationship that allows for different and asymmetric responses to positive and negative oil price changes. Moreover, the study employed time-varying pass-through coefficients within the framework of state-space models. The results showed asymmetric impacts between positive and negative oil prices changes on inflation, and the positive oil price shocks had a larger effect than negative ones, moreover employing inflation targeting policy increases the pass-through for oil price decreases and therefore reduces the asymmetry.

When a country is a large importer of oil, studying the impacts of global oil price changes on inflation owns a great concern. In this context, Long & Liang (2018) studied the pass-through impacts of crude oil price fluctuations on inflation measured by consumer and producer price indices in China. The study employed a linear and non-linear autoregressive distributed lag models. Results confirmed the asymmetric impacts of global oil price changes on inflation. This non-linear relationship which has been analyzed and confirmed in an augmented Phillips curve framework showed that, in the long- run, the impacts of the rise in global oil prices were greater than the impacts of oil prices decline on both indices of inflation. The same result compatible with other studies like Ibrahim & Chancharoenchai (2014) for Thailand, and Chou & Lin (2013) for Taiwan. This result implies that an asymmetric and nonlinear approach is necessary to explore the impacts of oil price changes on inflation.

For Malaysia, Ibrahim (2015) studied the effects of oil prices on food prices using a nonlinear autoregressive lag model to test the asymmetry in the long and short run. His findings supported asymmetric co-integration among oil prices and food price, the impacts of the oil price increase and food prices was significant in both, long and short runs, but was absent when oil prices fall in both time terms.

Also, Choi et al. (2018) studied the effects of oil prices on inflation in a large unbalanced sample of 72 advanced and developing economies spanning the period from 1970 to 2015. Results indicated that a 10% increase in global oil prices pushed domestic inflation by about 0.4%. Moreover, the asymmetry of oil prices pass-through has been proved, the positive oil price shocks have affected inflation more than the negative ones.

The impacts of oil price shocks on macroeconomic performance and on inflation were investigated by Cunado & De Gracia (2005) for six Asian countries. The study analyzed quarterly data covering the period (1975-2002) and applied an asymmetric model to examine the nonlinear effects of both the rise and decline of oil prices on inflation. Results suggested a significant effect of oil prices on both economic activity and price indexes, although the impact of oil prices was limited in the short run and more significant when oil price shocks are defined in local currencies. Moreover, there was evidence of asymmetries in the oil prices–macroeconomy relationship for some of the Asian countries.

While there are many studies focusing on analyzing the main determinants of inflation in Egypt, e.g., (Ahmed & Abdelsalam, 2017; El-Sakka & Ghali, 2005; Giugale & Dinh, 1990; Helmy, Fayed, & Hussien, 2018; Hosny, 2013), there is no pure study investigated the asymmetric impacts of oil prices fluctuations on inflation. For example, Iwayemi & Fowowe (2011) estimated vector auto-regression for Egypt and three exporting countries in Africa over the period 1970 to 2006. The results for Egypt indicated that oil price shocks did not Granger-cause consumer price index inflation during this period, where Egypt was still a net exporting country, and only in the short run, the decrease of oil prices, had a significant impact on GDP deflator. While M. H. Berument, Ceylan, & Dogan (2010) applied a Structural VAR to estimate the effects of oil prices on some macroeconomic indicators for the Middle East and North African countries (MENA). For Egypt, results showed no significant effects of oil price shocks on economic growth during the period 1952-2005 Belke & Dreger (2015).

3. Data Description and Methodology

3.1 Data

This study uses annual time series data during the period (1960-2017) and covering the variables of the following function:

$$P_t = F(OIL_t,\ GDPPC_t, M_t) \qquad (1)$$

where P_t denotes the logarithm of the consumer price index, OIL represents the logarithm of oil price in $US dollars, $GDPPC$ refers to the logarithm of real gross domestic product per capita, and M is the logarithm of real broad money. The definitions and sources of the variables are reported in Table 1, and t refers to the time unit (year).

Table (1): Definitions and sources of variables

Variable*	**Definition**	**Source**
$\boldsymbol{P}$	The inflation rate, consumer price index (2010=100)	World Development Indicators (WB, 2019)
$\boldsymbol{OIL}$	Oil price in $US per crude barrel of Arabian light for the period (1972-1986) and Dubai spot price for the period (1987-2017)	Statistical review of world energy of British Petroleum (BP, 2019).
$\boldsymbol{GDPPC}$	Real gross domestic product per capita (2010=100) in local currency.	World Development Indicators (WB, 2019)
$\boldsymbol{M}$	Real broad money (M2) (2010=100) in local currency.	World Development Indicators (WB, 2019)

**All variables are expressed in natural logarithm.*

Table 2 reports the data statistical characteristics such as mean, median, standard deviation, skewness, kurtosis, and Jarque-Bera statistics for consumer price index, oil prices, GDP and money supply for the period (1960-2017). It shows that the differences between the minimum and maximum values of all these variables are considered big enough, especially for both inflation and oil prices. Moreover, the standard deviations for these variables, comparing with their means, indicate considerable variability in each variable as shown in Fig. 1. The skewness values are negative and different from zero for all variables except oil prices and kurtosis is less than 3 for all variables which supports a high probability of potential asymmetry for these variables during the selected period.

Table (2): Descriptive statistics (1960-2017)[a]

Var.	**Mean**	**Median**	**Max.**	**Min.**	**Std. Dev.**	**Skewness**	**Kurtosis**	**Jarque-Bera**
P	9.69	9.96	29.50	-3.00	6.85	0.46	2.93	2.06
OIL	2.75	2.96	4.72	0.59	1.32	-0.52	2.13	4.38
GDPPC	9.76	9.86	10.49	8.91	0.50	-0.19	1.69	4.49
M	24.34	24.80	28.80	20.00	2.78	-0.16	1.62	4.86*

[a] All variables are expressed in natural logarithm. * denotes to significant at 10% level.

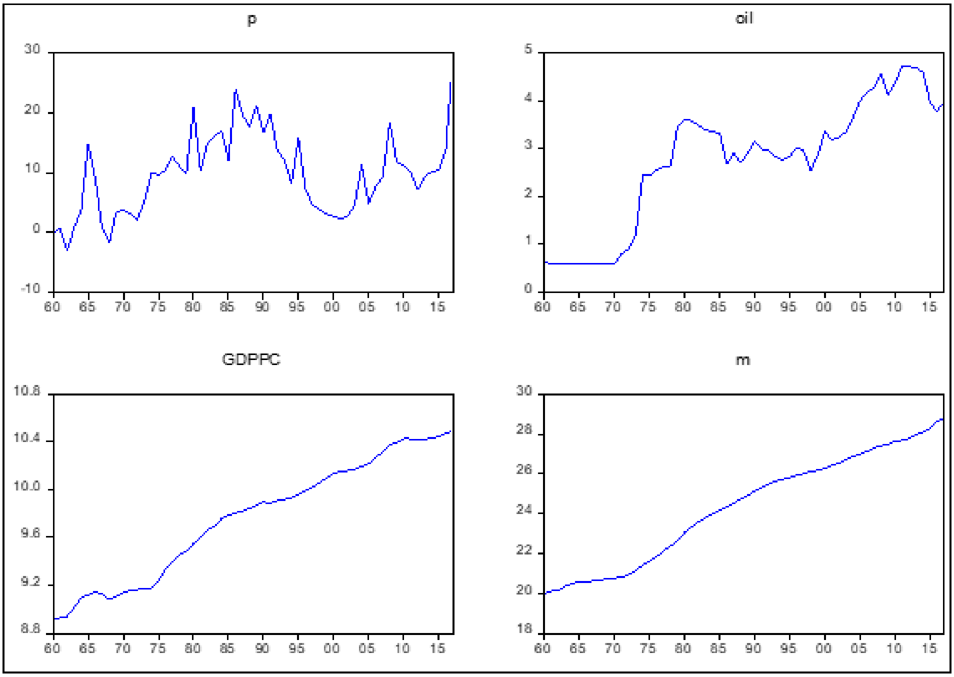
It is also necessary to explore the multicollinearity among the independent variables of the model. The results of Table 2 indicate that the value of the variance inflation factor (VIF) is less than 5 in all variables, which means that the model does not suffer from the problem of multicollinearity.

Table (3): Variance inflation factor test for multicollinearity

Var.	VIF	1/VIF
GDPPC	2.34	0.43
M	1.25	0.80
OIL	3.50	0.29
Mean VIF	2.36	

Note: VIF is computed by the author using STATA 15.

Fig. 1: Time path of variables in natural logarithm (1960-2017)



3.1 Linear ARDL

Contemporary studies apply several models in estimating the inflationary impacts of oil price changes, including the augmented Phillips curve model, where oil price change is adding as an independent variable with the output gap, for example, Long & Liang (2018). But in formulating the on hand model, the present study adds oil prices to the main factors that theoretically have a considerable effect on the inflation rate, such as money supply and gross domestic product. The impacts of these two factors have been investigated empirically in many studies, for example, Cukierman (2017), Eggoh & Khan (2014) and El-Shagi & Giesen (2013). Then the main equation can be formulated as follows:

$$P_t = a_0 + a_1 OIL_t + a_2 GDPPC_t + a_3 M_t + \epsilon_t \qquad (2)$$

where a_0 and $\in_t$ refer to the constant and error term respectively, all variables are defined according to Table (1) and are expressed in natural logarithms. The coefficients a_1, a_2 and a_3 represent the elasticities of the dependent variable, inflation, with respect to the explanatory variables, oil prices, gross domestic product per capita, and broad money, respectively.

A popular method in testing the long-and short-run relationships between variables is the autoregressive distributed lag model (ARDL) of Pesaran, Shin, & Smith (2001) which has many advantages in comparison with the traditional models for testing co-integration, like Engle & Granger (1987) or Johansen & Juselius (1990). The most important advantage of the ARDL model is its ability to test the existence of co-integration between time series that have different degrees of integration As long as the degree of integration of any variable does not exceed I(1). More advantages of the ARDL approach for testing co-integration are mentioned in: (Akalpler & Hove, 2019; Ali, Abdullah, & Azam, 2017). Eq. 2 can be reformulated in an ARDL model to know the behavior and relationships amongst variables in both long- and short-run as follows:

$$\begin{aligned}\Delta P_t = \alpha_0 &+ \sum_{i=1}^{k} \beta_i \Delta P_{t-i} + \sum_{i=0}^{l} \gamma_i \Delta Oil_{t-i} \\ &+ \sum_{i=0}^{n} \delta_\text{i} \Delta GDPPC_{t-i} + \sum_{i=0}^{q} \varphi_i \Delta M_{t-i} + \rho_1 P_{t-1} + a_1 OIL_{t-1} \\ &+ a_2 GDPPC_{t-1} + a_3 M_{t-1} \\ &+ \epsilon_t \qquad (3)\end{aligned}$$

where Δ refers to the first difference and $k, l, n, and\ q$ are the optimal lag lengths selected according to appropriate information criteria. The coefficients: β_i,γ_i, δ_i and φ_i represent the short-run relationships, whereas the coefficients: ρ_1, a_1, a_2 and a_3 represent the behavior of the model in the long run. The existence of a long-run relationship is checked via the joint F-statistic or Wald statistic by testing the null hypothesis of no co-integration (H_0: $\rho_1 = a_1 = a_2 = a_3 = 0$) against the alternative hypothesis of co-integration (H_1: $\rho_1 \neq a_1 \neq a_2 \neq a_3 \neq 0$). The co-integration will be confirmed if the F-statistic is greater than the upper bound critical value tabulated in (Pesaran et al., 2001) and will be denied if it is less than the lower bound critical value. If the F- statistic is between the upper and lower bounds, then the relationship between variables will be inconclusive.

Eq. (3) will be estimated after determining the optimal lag length for every variable of the model, using the Akaike Information Criterion (AIC) and Schwartz Bayesian Criterion (SBC). If there exists a long-run relationship between the variables, then the error correction model is estimated according to Eq. (4).

$$\Delta lP_t = \alpha_0 + \sum_{i=1}^{k} \beta_i \Delta P_{t-i} + \sum_{i=0}^{l} \gamma_i \Delta Oil_{t-i} + \sum_{i=0}^{n} \delta_i \Delta GDPPC_{t-i} + \sum_{i=0}^{l} \varphi_i \Delta M_{t-i} + \emptyset ECT_{t-1} + \epsilon_t \quad (4)$$

where $\emptyset$ refers to the coefficient of one lagged error correction term ECT which represents the adjustment speed of the model to return the long-run equilibrium path after a shock in the short-run.

3.2 Non-linear ARDL

Although the ARDL model offers many advantages when examining co-integration between variables, it is still a linear model that does not have the ability to distinguish the asymmetric effects of increasing or decreasing values of any independent variable. In this context, Shin, Yu, & Greenwood-Nimmo (2014) extended ARDL model of Pesaran et al. (2001) to capture the potential nonlinear or asymmetric short-and long-run relationships among variables. This nonlinear autoregressive distributed lag model (NARDL) has been utilized in many recent studies (Cheng & Cao, 2019; Choi et al., 2018; Lacheheb & Sirag, 2019), and can be formulated as follows:

$$P_t = a_0 + a_1^+ OIL_t^+ + a_1^- OIL_t^- + a_2 GDPPC_t + a_3 M_t + \epsilon_t \quad (5)$$

where OIL_t^+ and OIL_t^- are partial sums of positive and negative changes in oil prices OIL_t and computed as follows:

$$OIL_t^+ = \sum_{i=1}^{t} \Delta OIL_i^+ = \sum_{i=1}^{t} max\,(\Delta OIL_i\,, 0) \quad (6)$$

$$OIL_t^- = \sum_{i=1}^{t} \Delta OIL_i^- = \sum_{i=1}^{t} min\,(\Delta OIL_i\,, 0) \quad (7)$$

By replacing both OIL_t^+ and OIL_t^- instead of Oil in Eq. (3), the NARDL to estimate the asymmetric effects of oil prices on inflation can be formulated according to Eq. (8)

$$\Delta P_t = \alpha_0 + \sum_{i=1}^{k} r_i \Delta P_{t-i} + \sum_{i=0}^{l} \vartheta_i^+ \Delta OIL_{t-i}^+ + \sum_{i=0}^{m} \omega_i^- \Delta OIL_{t-i}^- + \sum_{i=0}^{n} \tau_i \Delta GDPPC_{t-i} + \sum_{i=0}^{o} \psi_i \Delta M_{t-i} + \theta_0 P_{t-1} + \theta_1^+ OIL_{t-1}^+ + \theta_1^- OIL_{t-1}^- + \theta_2 GDP_{t-1} + \theta_3 M_{t-1} + \epsilon_t \quad (8)$$

where Δ refers to the first difference, $r_i, \vartheta_i^+, \omega_i^-$, τ_i and ψ_i are the short-run coefficients, and θ_0, θ_1^+, θ_1^-, θ_2 and θ_3 are the long-run coefficients and ϵ_t is the error term. As in the linear ARDL model, F-statistic is employed to test for asymmetric co-integration in Eq. (5) by testing the null hypothesis of no asymmetric co-integration $(H_0: \theta_0 = \theta_1^+ = \theta_1^- = \theta_2 = \theta_3 = 0)$ against the alternative hypothesis of asymmetric co-integration $(H_1: \theta_0 \neq \theta_1^+ \neq \theta_1^- \neq \theta_2 \neq \theta_3 \neq 0)$. Wald test is used to test the null hypothesis of long-run asymmetries of positive and negative oil prices. If we failed to accept the null hypothesis of symmetry $(H_0: a_1^+ = a_1^-)$, where $(a_1^+ = -\frac{\theta_1^+}{\theta_0})$ and $(a_1^- = -\frac{\theta_1^-}{\theta_0})$, then the long-run asymmetry of the effects of positive and negative oil prices on inflation will be confirmed, otherwise, we will accept the long-run symmetry hypothesis.

Asymmetric effects in short-run of positive and negative oil prices on inflation can also be tested by the Wald test of the null hypothesis of symmetry $(H_0: \sum_{i=0}^{l} \vartheta_i^+ = \sum_{i=0}^{m} \omega_i^-)$ against the alternative $(H_0: \sum_{i=0}^{l} \vartheta_i^+ \neq \sum_{i=0}^{m} \omega_i^-)$. Finally, the positive and negative dynamic multipliers associated with a unit change of a_1^+ and a_1^- can be captured as follows:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial p_{t+j}}{\partial OIL_t^+}, \quad m_h^- = \sum_{j=0}^{h} \frac{\partial p_{t+j}}{\partial OIL_t^-}, \qquad h = 0,1,2,3 \ldots \quad (9)$$

In Eq. (9), when $h \to \infty$, then $m_h^+ \to a_1^+$, and $m_h^- \to a_1^-$, where both a_1^+ and a_1^- are the long-run coefficients that capture the asymmetric effects of oil price changes on inflation.

4. Results and discussion

4.1 Unit root tests

The first step in the empirical analysis is focusing on stationarity testing of all the time series used to determine the integration order of every variable of the model. This step is necessary to investigate whether the essential precondition of integration degree is met or not. According to Pesaran et al. (2001), the ARDL model is not valid if the degree of integration of any variable is greater than one. The results of traditional unit root tests are tabulated in Table 3, where ADF, PP tests confirm that the degree of integration is I(1) for all the variables, then we can generate the ARDL model.

Table (3): Unit root tests

Variables	**ADF**		**PP**	
	Level	1st. Diff.	Level	1st. Diff.
P	-1.911684	-9.198993***	-2.282730	-9.384544***
OIL	-1.337490	-6.587149***	-1.350700	-6.612079***
GDP	-1.999990	-4.528548***	-1.065330	-4.539560***
M	-1.998784	-3.071332**	-0.047302	-3.090902**

Notes: ADF and PP denote Augmented Dickey-Fuller and Phillips-Perron respectively. ***; ** and * denote to significance at the 1, 5 and 10% levels respectively. Optimal lags have chosen using the Schwarz information criterion (SIC).

4.2 Linear ARDL results

Table 3 presents the estimation results of equations (4) and (5), which assume the linearity of the relationship between variables of the model. Results of linear ARDL(2, 0, 0, 1) show that it is difficult to confirm or reject the existence of a co-integration among the variables, as the F-statistic value (2.98) is confined between the critical values of the upper and lower bounds of Pesaran et al. (2001), therefore, the decision is inconclusive at 10% level of significance. This result also reveals that all model's coefficients except the coefficient of money supply are insignificant in the long-run, which considered not realistic. These results contradict with many empirical studies that analyzed the oil changes pass-through and confirmed a positive and significant effect of oil price changes on the inflation rate in many developed, developing and emerging economies (e.g. Hammoudeh & Reboredo, 2018; Nusair, 2019; Tiwari et al., 2019). So, this contradiction of the linear ARDL raises more doubts about the reliability of its results and paves the way to explore the relationship between the variables in a non-linear framework using the nonlinear ARDL model.

Table (4): Linear ARDL(2, 0, 0, 1)[a] results

Variable	Coefficient	Std. Error	t-Statistic	P-value
Long-run estimates				
OIL	-0.27	0.182550	-1.519032	0.1352
$GDPPC$	0.60	1.305816	0.466988	0.6426
M	0.39***	0.103828	3.822281	0.0004
C	-11.66	10.26978	-1.136322	0.2613
Sort-run estimates				
ΔP_{-1}	0.29***	0.074709	4.007941	0.0002
ΔM	0.34***	0.033020	10.32847	0.0000
ECT_{-1}	-0.10***	0.024868	-4.372047	0.0001
Bound test				
F-Statistics	2.98			
Diagnostic tests				
Adj.R2	0.80			
LM test	1.17 [0.5568]			
Norm. test	5.16* [0.0755]			
Hetero. test	9.84[0.1314]			

Notes: [a] Model selection method: Akaike information criterion (AIC). ***; ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Numbers in square brackets are P-values.

Table (5): Bounds test for linear ARDL(2, 0, 0, 1)

F_{pss}-Statistic	Significant level	Lower Bound I(1)	Upper Bound I(0)
	1%	4.66	3.65
2.98	5%	3.67	3.79
	10%	3.2	2.37

Note: The bounds critical values are taken from Pesaran et al. (2001) with unrestricted intercept and no trend.

4.3 NARDL results

Results of estimating the Nonlinear ARDL (5, 2, 2, 2, 5) model expressed in Eq. 8 are reported in Tables 6&7. The results show that there is a co-integration amongst inflation, oil prices, GDPPC, and money supply in the Egyptian economy over the period 1960-2017. The value of F-statistic is 4.41 which is greater than the critical value of the upper bound tabulated in Peseran et al. (2001). The error correction term ECT is negative and highly significant which implies the existence of a long-run equilibrium relationship between variables and the system can be returned to the equilibrium path by 73.2% per year. Moreover, the model doesn't suffer from heteroskedasticity or autocorrelation and has a normal distribution. The stability of the model is confirmed by CUSUM and CUSUM of Squares tests depicted in Fig. 2. The results of the study are consistent with the results of many studies, such as Long & Liang (2018), Ibrahim & Chancharoenchai (2014), and Chou & Lin (2013). Detailed results can be discussed as follows:

- In the short-run, the positive and negative changes in oil prices have a significant impact on inflation, but the positive effect is greater than and more significant in comparison with the negative effect of oil prices. Results show that a 1% increase in oil price will push inflation rate up by 0.6%, while a 1% decrease in oil prices will reduce inflation by just 0.04% in the short run. Agin these results confirm that, in the short-run, the inflation response to oil prices decrease is inelastic, while its response to oil prices increase is highly significant, positive, and more elastic.
- The Wald test of asymmetry confirms the asymmetric impacts of oil price changes on the inflation rate in Egypt in both the short and long-runs, which consistent with other studies such as (Chen, Zhu, & Li, 2020; Lacheheb & Sirag, 2019; Salisu et al., 2017)

Table (6): Nonlinear ARDL (5, 2, 2, 2, 5)[a] results

Variable	Coefficient	Std. Error	t-Statistic	P- value
Long-run estimates				
OIL^{+}	0.03	0.027090	1.178119	0.2477
OIL^{-}	-0.19***	0.047636	-4.121737	0.0003
$GDPPC$	-1.07***	0.244227	-4.413068	0.0001
M	0.43***	0.025666	16.94033	0.0000
C	3.08	1.869624	1.651821	0.1087
Sort-run estimates				
ΔP_{-1}	0.63***	0.157811	4.043123	0.0003
ΔP_{-2}	0.51***	0.179207	2.895267	0.0069
ΔP_{-3}	0.16	0.173674	0.970890	0.3391
ΔP_{-4}	0.56***	0.165768	3.388171	0.0019
ΔOIL^{+}	0.60***	0.189854	3.202724	0.0020
ΔOIL^{+}_{-1}	0.03*	0.020074	1.982499	0.0563
ΔOIL^{-}	-0.05**	0.027344	-2.055107	0.0484
ΔOIL^{-}_{-1}	0.08***	0.030514	2.869927	0.0073
$\Delta GDPPC$	-0.21	0.232531	-0.913547	0.3680
$\Delta GDPPC_{-1}$	0.37	0.231483	1.617165	0.1160
ΔM	0.24***	0.061138	3.935243	0.0004
ΔM_{-1}	0.18*	0.105187	1.796713	0.0821
ΔM_{-2}	0.34***	0.111623	3.063316	0.0045
ΔM_{-3}	0.07	0.100016	0.771254	0.4464
ΔM_{-4}	0.20**	0.097901	2.137398	0.0406
ECT_{-1}	-0.73***	0.132161	-5.540330	0.0000
Bound test				
F-Statistics	4.41***			
Asymmetry test				
W_{LR}	16.34***[0.0003]			
W_{SR}	8.38***[0.0002]			
Diagnostic tests				
Adj.R²	0.96			
LM test	2.46[0.2910]			
Norm test	1.01 [0.604]			
Hetero test	28.66[0.1222]			

Notes: [a] Model selection method: Akaike information criterion (AIC). ***; ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. W_{LR} and W_{SR} are Wald test for asymmetry in the long-run and short-run respectively. Numbers in square brackets are P-values.

Table (7): Bounds test for nonlinear ARDL (5, 2, 2, 2, 5)

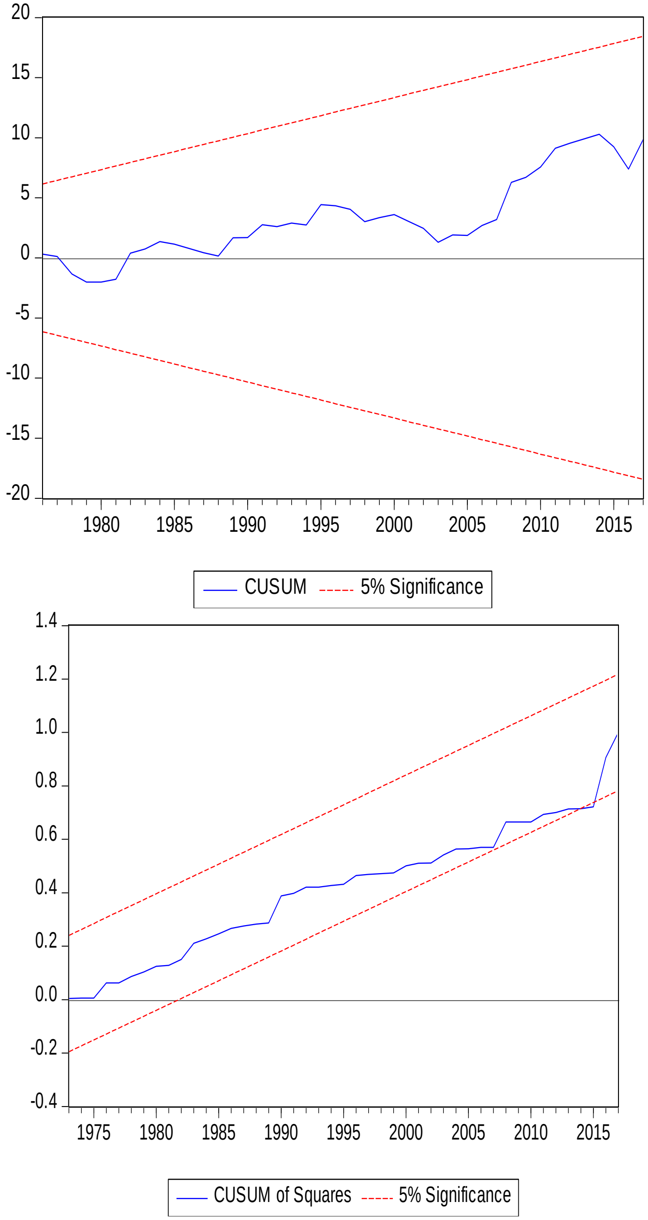
F_{pss}-Statistic	Significant level	Upper Bound I(1)
	1%	4.37
4.41* **	5%	3.49
	10%	3.09

Note: The bounds critical values are taken from Pesaran et al. (2001) with unrestricted

- Economic growth proxied by the logarithm of gross domestic product per capita was highly significant in effecting the inflation rate in the long-run. A 1% increase in GDPPC leads to reduce the inflation rate by 1.07% in the long run. This result reveals that real economic growth is the key factor in reducing the inflation rate in the Egyptian economy in the long run. However, the results indicate that the effect of economic growth on the inflation rate was not significant within the short-run. This corresponds to the nature of the markets in the Egyptian economy, as prices do not respond quickly to increasing economic growth due to the proliferation of monopolistic practices in the Egyptian market, which hinder market mechanisms from right and quick adjustments.

- The effect of the money supply on inflation is positive and highly significant in the long term. An increase in the broad money supply (M2) by 1% will result in an increase of 0.43% per year in the consumer price index. Although most of the elasticities of the money supply were positive and significant in the short-run, they were less than the unity, which means that the rate of money growth is not fully reflected in rising inflation rates in the Egyptian economy in the short term. This limited effect of money supply growth on inflation in Egypt in the short-run means that the increase in money supply will not have a considerable effect on long-term inflation, because the increase in money supply does not go directly to increase the aggregate demand to purchase goods and services, instead, this increase goes to take advantage of investment in high-interest deposits that enable depositors to have a relatively stable income to compensate for their low real incomes. This may be compatible with the nature of the Egyptian economy, when money supply is increasing, this increase is mainly directed towards investment certificates with interest rates reached to 20% in 2018, CBE (2018).

Fig. (2): CUSUM and CUSUMQ tests for stability of the model



5. Conclusion and policy implications

This study applies the NARDL methodology to test the nonlinear relationship between inflation and the change in oil prices in the Egyptian economy during the period 1960-2017. The study is conducted in a comparative framework to identify the deficiencies that may result from the application of the linear ARDL methodology. Results of the co-integration test among the model variables were quite different in the case of ARDL compared to the NARDL model. While the linear model was unable to confirm or reject the existence of co-integration among variables as the F-statistic is less than the critical value of the higher bound and greater than the critical value of the lower bound, however, results of the NARDL model confirmed a long-run equilibrium relationship between inflation, oil prices, GDP, and money supply as the F-statistic is higher than the critical value of the higher bound at 1% level of significance. This means that analyzing the relationship between variables in a linear framework may lead to misleading results for the economic policymakers, then it is necessary to test the co-integration among variables in a non-linear framework. In other words, the nonlinear relationship between the variables should be considered as a general case that must be initiated at the first stage of model formulation, and that the linear relationship is a special case that is realized only if the asymmetric effect is not proven. Testing asymmetry confirms the asymmetric impacts of oil price changes on the inflation rate in Egypt in both the short-run and long-run. While the effect of oil price increase is not significant in the long run in comparison with the negative effect of oil prices, in the short-run, the positive and negative changes in oil prices have a significant impact on inflation, but the positive effect is greater than and more significant in comparison with the negative effect of oil prices. These results pose challenges that minimize the ability of the Central Bank of Egypt in controlling inflation rates in Egypt in the short-run because changes in oil prices are determined globally and outside the scope of its monetary policy. Even if these prices fall, according to the NARDL results of this study, these reductions are not reflected in reducing inflation rates in Egypt.

References

Ahmadov, V., Huseynov, S., & Pedroni, P. (2018). *Oil Prices and Inflation: Identifying Channels for Oil Exporters* (No. 1801).

Ahmed, D. A., & Abdelsalam, M. A. M. (2017). Modelling and forecasting inflation in Egypt: univariate and multivariate approaches. *Middle East Development Journal, 9*(1), 127-159.

Akalpler, E., & Hove, S. (2019). Carbon emissions, energy use, real GDP per capita and trade matrix in the Indian economy-an ARDL approach. *Energy*, *168*, 1081-1093.

Ali, W., Abdullah, A., & Azam, M. (2017). Re-visiting the environmental Kuznets curve hypothesis for Malaysia: Fresh evidence from ARDL bounds testing approach. *Renewable and Sustainable Energy Reviews, 77*, 990-1000.

Álvarez, L. J., Hurtado, S., Sánchez, I., & Thomas, C. (2011). The impact of oil price changes on Spanish and euro area consumer price inflation. *Economic Modelling*, 28(1), 422–431.

Barsky, R. B., & Kilian, L. (2004). Oil and the Macroeconomy Since the 1970s. *Journal of Economic Perspectives*, *18*(4), 115-134.

Baz, K., Xu, D., Ampofo, G. M. K., Ali, I., Khan, I., Cheng, J., & Ali, H. (2019). Energy consumption and economic growth nexus: New evidence from Pakistan using asymmetric analysis. Energy, 189, 116254.

Belke, A., & Dreger, C. (2015). The transmission of oil and food prices to consumer prices. *International Economics and Economic Policy*, *12*(1), 143-161.

Berument, H., & Taşçı, H. (2002). Inflationary effect of crude oil prices in Turkey. *Physica A: Statistical Mechanics and its Applications, 316*(1-4), 568-580.

Berument, M. H., Ceylan, N. B., & Dogan, N. (2010). The Impact of Oil Price Shocks on the Economic Growth of Selected MENA Countries. *The Energy Journal*, *31*(1), 149-176.

Bhattacharya, K., & Bhattacharyya, I. (2001). Impact of increase in oil prices on inflation and output in India. *Economic and Political weekly*, 4735-4741.

BP. (2019). Statistical review of world energy. Retrieved from https://www.bp.com/en/global/ corporate/energy-economics/statistical-review-of-world-energy.html

Cavalcanti, T., & Jalles, J. T. (2013). Macroeconomic effects of oil price shocks in Brazil and in the United States. *Applied Energy*, 104, 475–486.

Cerra, V. (2019). How can a strong currency or drop in oil prices raise inflation and the black-market premium? *Economic Modelling, 76*, 1-13.

Chen, S.-S. (2009). Oil price pass-through into inflation. *Energy Economics, 31*(1), 126-133.

Cheng, S., & Cao, Y. (2019). On the relation between global food and crude oil prices: An empirical investigation in a nonlinear framework. *Energy Economics, 81*, 422-432.

Choi, S., Furceri, D., Loungani, P., Mishra, S., & Poplawski-Ribeiro, M. (2018). Oil prices and inflation dynamics: Evidence from advanced and developing economies. *Journal of International Money and Finance, 82*, 71-96.

Chou, K.-W., & Lin, P.-C. (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.

Cologni, A., & Manera, M. (2008). Oil prices, inflation and interest rates in a structural cointegrated VAR model for the G-7 countries. *Energy Economics, 30*(3), 856-888.

Cukierman, A. (2017). Money growth and inflation: Policy lessons from a comparison of the US since 2008 with hyperinflation Germany in the 1920s. *Economics Letters, 154*, 109-112.

Cunado, J., & De Gracia, F. P. (2005). Oil prices, economic activity and inflation: evidence for some Asian countries. *The Quarterly Review of Economics and Finance, 45*(1), 65-83.

Cuñado, J., & de Gracia, F. P. (2003). Do oil price shocks matter? Evidence for some European countries. *Energy Economics, 25*(2), 137-154.

Darby, M. R. (1982). The price of oil and world inflation and recession. *The American Economic Review, 72*(4), 738-751.

Eggoh, J. C., & Khan, M. (2014). On the nonlinear relationship between inflation and economic growth. *Research in Economics, 68*(2), 133-143.

El-Sakka, M. I. T., & Ghali, K. H. (2005). The Sources of Inflation in Egypt A Multivariate Co-integration Analysis. *Review of Middle East Economics and Finance, 3*(3), 257-269.

El-Shagi, M., & Giesen, S. (2013). Money and inflation: Consequences of the recent monetary policy. *Journal of Policy Modeling, 35*(4), 520-537.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 251-276.

Giugale, M., & Dinh, H. T. (1990). *Money, inflation, and deficit in Egypt* (Vol. 553): World Bank Publications.

Hamilton, J. D. (1996). This is what happened to the oil price-macroeconomy relationship. *Journal of Monetary Economics, 38*(2), 215-220.

Hammoudeh, S., & Reboredo, J. C. (2018). Oil price dynamics and market-based inflation expectations. Energy Economics, 75, 484–491.

Helmy, O., Fayed, M., & Hussien, K. (2018). Exchange rate pass-through to inflation in Egypt: a structural VAR approach. *Review of Economics and Political Science, 3*(2), 2-19.

Hosny, A. (2013). Inflation in Egypt: Internal or External Driven? *Middle East Development Journal, 5*(3), 1350019-1-1350019-15.

Ibrahim, M. H. (2015). Oil and food prices in Malaysia: a nonlinear ARDL analysis. *Agricultural and Food Economics, 3*(1), 2.

Ibrahim, M. H., & Chancharoenchai, K. (2014). How inflationary are oil price hikes? A disaggregated look at Thailand using symmetric and asymmetric cointegration models. *Journal of the Asia Pacific Economy, 19*(3), 409-422.

Istiak, K., & Alam, M. R. (2019). Oil prices, policy uncertainty and asymmetries in inflation expectations. *Journal of Economic Studies, 46*(2), 324-334.

Iwayemi, A., & Fowowe, B. (2011). Oil and the macroeconomy: empirical evidence from oil-exporting African countries. *OPEC Energy Review, 35*(3), 227-269.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. *Oxford Bulletin of Economics and Statistics, 52*(2), 169-210.

Lacheheb, M., & Sirag, A. (2019). Oil price and inflation in Algeria: A nonlinear ARDL approach. *The Quarterly Review of Economics and Finance*.

Lardic, S., & Mignon, V. (2008). Oil prices and economic activity: An asymmetric cointegration approach. *Energy Economics, 30*(3), 847-855.

Liang, C. C., Troy, C., & Rouyer, E. (2019). U.S. uncertainty and Asian stock prices: Evidence from the asymmetric NARDL model. The North American Journal of Economics and Finance, 101046.

Lin, P.-C., & Wu, C.-S. (2012). Exchange rate pass-through in deflation: The case of Taiwan. *International Review of Economics & Finance, 22*(1), 101-111.

Long, S., & Liang, J. (2018). Asymmetric and nonlinear pass-through of global crude oil price to China's PPI and CPI inflation. *Economic Research-Ekonomska Istraživanja, 31*(1), 240-251.

López-Villavicencio, A., & Pourroy, M. (2019). Inflation target and (a)symmetries in the oil price pass-through to inflation. *Energy Economics, 80*, 860-875.

Mirdala, R. (2014). Exchange Rate Pass-through to Consumer Prices in the European Transition Economies. *Procedia Economics and Finance, 12*, 428-436.

Nusair, S. A. (2019). Oil price and inflation dynamics in the Gulf Cooperation Council countries. *Energy, 181*, 997–1011.

Nazlioglu, S., Gormus, A., & Soytas, U. (2019). Oil Prices and Monetary Policy in Emerging Markets: Structural Shifts in Causal Linkages. *Emerging Markets Finance and Trade, 55*(1), 105-117.

O'Neill, T., Penm, J., & Terrell, R. (2008). The role of higher oil prices: A case of major developed countries. In *Research in Finance* (pp. 287-299): Emerald Group Publishing Limited.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289-326.

Roeger, W. (2005). International oil price changes: impact of oil prices on growth and inflation in the EU/OECD. *International Economics and Economic Policy, 2*(1), 15-32.

Salisu, A. A., Isah, K. O., Oyewole, O. J., & Akanni, L. O. (2017). Modelling oil price-inflation nexus: The role of asymmetries. Energy, 125, 97–106.

Schorderet, Y. (2003). *Asymmetric cointegration*. Université de Genève/Faculté des sciences économiques et sociales Genève.

Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In *Festschrift in honor of Peter Schmidt* (pp. 281-314): Springer.

Tiwari, A. K., Cunado, J., Hatemi-J, A., & Gupta, R. (2019). Oil price-inflation pass-through in the United States over 1871 to 2018: A wavelet coherency analysis. Structural Change and Economic Dynamics, 50, 51–55.

Ullah, A., Xinshun, Z., Kamal, M. A., & JiaJia, Z. (2020). Modeling the relationship between military spending and stock market development (a) symmetrically in China: An empirical analysis via the NARDL approach. Physica A: Statistical Mechanics and Its Applications, 124106.

WB, (2019) World Development Indicators. The World Bank Group, Washington, DC, USA. http://data.worldbank.org/data-catalog/world-development-indicators (Accessed January 2019)

Wu, M.-H., & Ni, Y.-S. (2011). The effects of oil prices on inflation, interest rates and money. *Energy*, *36*(7), 4158-4164.