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Asymmetric Effects of Exchange Rates and Oil Prices on Inflation in Egypt

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ABSTRACT

This study aimed to examine the asymmetric effects of exchange rates and oil prices on inflation in Egypt using the nonlinear autoregressive distributed lag (NARDL) model. Relying on annual data during the period (1975-2023), the findings from the estimations in the long run show a negative impact of gross domestic product on inflation. While the money supply has a negative impact on inflation in both the long run and the short run, the asymmetric results indicate that positive changes in exchange rates lead to decreased inflation in both the long run and the short run, while negative changes in exchange rates result in increased inflation. Furthermore, both positive and negative changes in oil prices lead to increased inflation in the long and short run. From the study's results, the main triggering factors of inflation in Egypt are instability in the exchange rate, oil prices, and money supply. Therefore, following a contractionary monetary policy is essential to tighten the money supply and avoid instability in the exchange rate market. Moreover, to curb inflation, the Central Bank of Egypt must ensure a stable exchange rate by attracting foreign private investment through macroeconomic policies that incentivize foreign investors.

Keywords: Asymmetric Effects, Exchange Rate, Oil Prices, Inflation, NARDL Model
JEL Classifications: C22, F31, Q43, E31, C51

1. INTRODUCTION

Achieving and maintaining price stability by controlling inflation efficiently is a major responsibility of the central bank and monetary authorities. Efforts to maintain price stability have forced many countries to change their monetary policies within the monetary policy framework and the exchange rate regime used. Over the years, the exchange rate of many developing countries (such as Egypt) has been a critical issue of concern given its poor performance against the major trading currencies such as the US Dollar, Euro, and the Great British Pound. It is believed that the exchange rate has the potency to influence domestic policies, as poor exchange rate performance could translate into price instability in an economy, especially in import-dependent countries like Egypt.

Exchange rate changes affect domestic prices through direct and indirect channels. The openness of the economy increases the significance of both these channels (Hüfner and Schröder, 2002). The direct channel runs via the external sector of the economy, especially through the relative share of imports in CPI (Aron et al., 2014). The depreciation in the exchange rate increased the prices of imported goods. Then, similarly, the producers and importers increased their prices and ultimately transferred them into producer prices, and the economy's CPI caused higher inflation. (Goldberg and Knetter, 1997) Assert the transmission effect is complete when markup and marginal costs are fixed. When markup and marginal costs are fixed, producers do not apply any price discrimination, and the import prices will change in proportion to exchange rate changes. The higher the pricing power to market, the lower the transmission rate effect. Also, the pass-through to both consumer and import prices is be stronger when markets and consumers expect high inflation rates in the future; this suggests that anchoring inflation expectations helps to reduce the effect of exchange rate (Anderl and Caporale, 2023).

The indirect channel of the exchange rate is driven by inflation expectations and changes in the levels of aggregate demand and wages (Ho and McCauley, 2003). The highest exchange rate will be observed if the changes in the exchange rate are professed to be persistent and the public's expectations are adjusted by the price (Taylor, 2000). Another exchange rate channel runs via increased aggregate demand for domestic goods. The depreciation of the exchange rate causes domestic goods to become cheaper in the international market, which increases the country's exports and domestic demand for goods. This increase in demand for goods puts pressure on prices and output in the short run. In the long run, prices will stabilize at new high prices and decrease output (Ahn et al., 2016).

Similarly, if the supply of goods is rigid, the indirect channel of the exchange rate puts pressure on the supply of goods, and exchange rate depreciation will increase the exports, causing a shortage of the supply of the commodity and ultimately increasing the domestic prices (Raisi and Pattanaik, 2005). The direct exchange rate channel to domestic prices dominates the indirect channel; if the import intensity of exports in the economy is higher, a faster adjustment in prices and wages occurs. On the other hand, the direct channel of the exchange rate may be verified to be weak if the economy is more diversified and if depreciation increases the production of domestic substitutes and domestic demand is reduced by the rise in the price of imported goods (Hong and Zhang, 2016).

The impact of oil price shocks on domestic inflation and exchange rate happens via two channels: The direct and indirect channels. The direct channel is related to variations in a firm's production cost induced by an increase or decrease in energy resources. In contrast, the indirect channel is associated with the fluctuations in exchange rates caused by rising and falling oil prices. (López-Villavicencio and Pourroy, 2019). When the crude oil price increases in the international oil market, retail oil marketers will swiftly raise the pump price to uphold their habitual profit margin and avoid losses. Because refined oil is assumed to be one of the factors of production for industrial products, an increase in oil prices will lead to an increase in the cost of production, and quite a number of products will rise, hiking the producer and consumer prices (PPI and CPI, respectively). Energy (oil), along with labor and capital, is considered a key input into the production process that transforms factors of production into goods and services. As a result, a unit increase in energy costs will pass through to production costs and the domestic prices of finished goods. The effects of crude oil price shocks can be replicated to some magnitude by the reactions of raw material procurement costs and product Ex-factory prices to variations in oil prices (Zhu and Chen, 2019).

Furthermore, theories assert that if all things are equal, higher or lower crude oil prices will result in a higher or lower cost of operation in many industrial enterprises, and the rise in production costs will be passed on to finished goods prices. Exorbitant oil prices in the global market translate to increases in production costs, leading to a shortage in the aggregate supply of goods and services, resulting in inflation and a fall in production. On the other side, rising oil prices, whether sudden or expected, will increase oil-based revenues for oil-producing economies, which will consequently increase the money supply, which increases government expenditure due to an increase in petro-dollar revenue, which will lead to an increase in money supply and real income in the system, then translate to inflation (Choi et al., 2018).

Generally, an increase in oil price gives multiple economic advantages to a net oil-exporting country, such as higher oil revenue. In contrast, it also has an adverse impact on the net oil-importing country, resulting in a higher cost of production and cost of living; regardless of whether or not it is an oil-exporting or importing country, an increase in oil price causes high inflation. Nevertheless, exchange rate depreciation also contributes to higher inflation, especially if a country depends too much on importing production inputs. Accordingly, oil prices and exchange rates are two important factors in determining price inflation; hence, it is essential to model them simultaneously.

Understanding the actual response of domestic inflation to the shocks of exchange rates and oil prices will guide monetary policymakers to design a sound and suitable policy to guard against any negative shocks of prices on a country's macroeconomy. When there is a sudden and unexpected increase in exchange rate and oil prices, which may increase domestic production costs, which may be passed on to domestic consumer prices, monetary policymakers may change their course to achieve the desired outcome. Monetary policy's emphasis may shift to regulating inflation from the wonky exchange rate or output handling.

Accordingly, this study attempts to show how inflation in Egypt responds to the exchange rate and oil price asymmetrically since both factors are important determinants for the inflation price. This is done using a standard methodology based on the non-linear autoregressive distributed lag (NARDL) model. During the period (1975-2021), The study problem can be formulated in the following two questions:

- Is the exchange rate's effect on Egypt's inflation rate the same in both the long and short run?
- Is the effect of the oil price on the inflation rate in Egypt the same in both the long and short run?

The remainder of this paper is arranged in the order below. The second section includes a literature review; the third discusses A Review of Egyptian Exchange Rate, Oil Price, and Inflation Developments; and the fourth discusses the methodology and data description. The fifth section discusses results and discussion. The sixth section discusses policy implications and the conclusion.

2. LITERATURE REVIEW

The research on the influence of macroeconomic factors on inflation, such as oil prices and currency rates, is well documented. Empirical studies have employed various variables, methodologies, samples, and data collection timeframes. Consequently, several analyses and views about the source of inflation correspond to the country's nature. This section reviews some literature relating to the impact of exchange rates and oil prices on inflation, which can be divided as follows:

2.1. Studies on Inflation and Exchange Rate

Over the years, researchers have examined the impact of exchange rates on inflation under different monetary policy frameworks. However, the magnitude and the speed of the exchange rate to inflation (high or low) remain an unsolved paradox. Ghosh (2014) revealed in a large panel dataset including 137 countries that exchange rate depreciation increases inflation in developed economies, developing markets, and low-income nations. Hossain and Arwatchanakarn (2017) found that the appreciation of the Thai currency cuts inflation significantly.

Yazdan and Soheila (2015) found an asymmetric long-term relationship between these variables (exchange rate and CPI) in the Iranian economy; the effect of negative shocks of exchange rate on inflation is more sustainable than the one from positive shocks. Similarly, Kassi et al. (2019) investigate the asymmetrical exchange rate pass-through (ERPT) to consumer prices for emerging and developing Asian countries; the results suggest an asymmetrical ERPT for local prices in the emerging Asian sub-region in the short and long-term and only in the short-term in the developing Asian sub-region. Second, this study finds a significant and complete ERPT for appreciation, higher during local currency appreciation than depreciation in the long term.

Dahem et al. (2017) study the evolution over time of the effect of monetary and exchange rate shocks on prices in Tunisia, finding a time-varying exchange rate and that the exchange rate into government-controlled prices (food and fuel) surges after the 2010-2011 political developments in that country. Baharumshah et al. (2017) examined the impact of the exchange rate on consumer prices in Mexico using the NARDL models and revealed an asymmetrical exchange rate in Mexico. The depreciation of the local currency was transmitted to prices more strongly than the appreciation, with a declining pass-through after 2001.

Kinda and Barry (2021) examined the impact of the exchange rate on import prices in West African economies, revealing that a 1% depreciation of the exchange rate resulted in a 0.25% increase in import prices. Their findings demonstrate that the exchange rate exerts a persistent and substantial influence on import prices, with a 1% increase in the exchange rate leading to a 0.83% increase in import prices. Ben Cheikh and Ben Zaied (2020) did similar research and revealed that the inflation regime serves as the primary driver of exchange rate pass-through (ERPT). The study finds that if inflation exceeds a threshold of 4.56%, the degree of ERPT in transition economies will be significantly high.

2.2. Studies on Inflation and Oil Price

More than a few studies have attempted to analyze the effect of oil prices on fluctuations in inflation in both oil-producing and oil-consuming countries. Another work conducted by Salisu et al. (2017) evaluated the impacts of oil price fluctuations on inflation by using a panel dataset consisting of countries that were either net oil buyers or net oil sellers. They found that countries with higher oil imports experience more inflation over the long term than countries with lower oil exports. Moreover, they revealed that the nonlinear influence of oil prices on inflation is clearer and more proven for nations that export oil.

Sek (2017) examined the symmetric and asymmetric pass-through effect of oil price changes on four domestic price indices in Malaysia. Results show evidence of symmetric and asymmetric pass-through effects of oil price changes on domestic prices across sectors. Oil price changes lead to the positive effect of higher output growth but may directly cause higher import and production prices in the long run through cost channels. On the other hand, oil price changes have a limited direct effect on consumer prices in the long run. The impact of oil prices on consumer prices occurs indirectly through transmission from import prices and production costs. Sectors that are more oil-intensive experience a larger impact of oil price changes.

Further, Choi et al. (2018), using a chosen sample of 72 nations at various economic levels for 1970-2015, revealed asymmetric effects, with oil price increases having a more significant influence than decreases in the selected sample. Similarly, Nusair (2019) investigated the oil price uncertainty-inflation asymmetric relationship in the Gulf Cooperation Council. According to the findings, favorable oil price fluctuations exert a greater influence on inflation in GCC countries than negative ones do. Furthermore, the asymmetry effect is more significant for Gulf Cooperation Council (GCC) countries in the long term.

Moreover, Bala and Chin (2018) investigated the asymmetric impacts of oil price changes on inflation in Algeria, Angola, Libya, and Nigeria. They found that both positive and negative oil price changes positively influenced inflation. However, the impact was found to be more significant when the oil prices dropped. Lacheheb and Sirag (2019) investigated the link between Algerian inflation and oil prices. found that asymmetrical, although the fact that increases in oil prices have a more substantial effect on Algerian inflation than decreases in oil prices. Li and Guo (2021) investigated the asymmetric impact of oil price and component shocks on inflation in BRICS countries by decomposing changes in oil price into supply, demand, and risk shocks. The results reveal that asymmetries exist between oil price and inflation in China in the short run. The result further suggests that the impact of oil price on inflation is more when oil price decreases.

Further, Garzon and Hierro (2021) analyzed asymmetries in the transmission of oil price shocks to inflation in the eurozone. Also found that revealed a higher transmission of positive shocks in high inflation environments. Core inflation was susceptible to oil price shocks only in high inflation environments.

On the other hand, Jiranyakul (2019) examined the impact of oil price shocks on the domestic inflation rate in Thailand and found no evidence of asymmetry. However, there is a positive relationship between oil prices and inflation in the long and short run.

Wang et al. (2017) examined the impact of oil price shocks on inflation and monetary policy in China. They revealed that oil price fluctuations significantly impact core inflation more than non-core inflation and headline inflation. Conflitti and Luciani (2019) estimated the oil price pass-through into consumer prices in the US and the euro area. The results show evidence of a pass-through from oil price to core inflation through macroeconomic factors; however, the pass-through is estimated to be small and long-lasting. Similarly, Zakaria et al. (2021) indicated that oil price shocks positively affect inflation in South Asian countries. It was found that positive oil price shocks increase inflation significantly, while the influence of negative oil price shocks is not significant, buttressing evidence of asymmetry.

Altunöz (2022) examines the pass-through of crude oil prices on the consumer prices index (CPI) and producer prices index (PPI) in Turkey; the results show that the effects of volatility in crude oil prices on Turkey's consumer price index and producer price index are not symmetrical in the long run. The long-term effects of the increase in international oil prices on the consumer price index and producer prices index are higher than in the case where international oil prices show reduction.

2.3. Studies on Inflation and Exchange Rate, Oil Price

Several studies have been conducted to shed light on the link between the currency exchange rate and inflation. Köse and Ünal (2021) studied how oil prices, Oil price volatility, labor expenses, and the exchange rate affected Turkish inflation, which stands for structural vector autoregression. They concluded that the impact of oil prices and price uncertainty varies over time. Hence, in the first few months of the investigation, the effect was found to be small, but it grew in the following months. Moreover, it was found that the largest factor influencing inflation in Turkey was the exchange rate.

(Mukhtarov et al., 2019) investigated the link between Azerbaijan's inflation, oil prices, and exchange rate. The results proved the presence of the variables' long-term association and demonstrated that the oil price changes and the currency exchange rate affect Azerbaijan's inflation positively.

Husaini and Lean (2021) examined the asymmetric impact of oil and exchange rates on the disaggregate price inflation in Indonesia, Malaysia, and Thailand. Given that each country has its own economic structure, the impact of oil price and exchange rate fluctuation on the price level may differ across the countries. We find that an increase in oil price has a more significant impact on the producer price index (PPI) than the consumer price index (CPI) in all countries. However, a decrease in the oil price is only significant in reducing both CPI and PPI in Thailand. Moreover, an increase in the exchange rate (currency depreciation) is significant in causing an increase in both the CPI and PPI in all countries. However, a decrease in the exchange rate (currency appreciation) failed to reduce the CPI and PPI in all countries.

Sa'ad et al. (2023) examine the asymmetric effect of oil price and exchange rate pass-through on inflation in Nigeria. The result of the asymmetric test revealed the existence of asymmetries among the study variables, suggesting a nonlinear interaction among the variables used in the study. Results of the long-run estimates show that rising (positive) oil price shocks have a more significant impact on inflation than falling (negative) oil price shocks. Moreover, the results suggest that positive oil price changes have a larger impact than negative ones and that the effect of an oil price shock on inflation and exchange rates is larger in the long run than in the short run.

From the above discussions, it is apparent that different authors have examined the relationships between exchange rates, oil prices, and inflation within different contexts. However, the study that investigates the effect of these variables on inflation in Egypt is scant in the literature, especially the asymmetric effect of these variables on inflation in Egypt. Thus, this study aims to fill the existing gaps and contribute to the literature.

3. A REVIEW OF THE EGYPTIAN EXCHANGE RATE, OIL PRICE AND INFLATION DEVELOPMENTS

This section deals with the development of the main variables of the study in Egypt during the period (1975-2023), which are the exchange rate, oil price, and inflation rate, as follows:

3.1. Analysis of the Development of the Exchange Rate in Egypt

The Egyptian economy suffered in the second half of the seventies and eighties from the phenomenon of imbalance in foreign exchange markets. The exchange rate of the Egyptian pound was characterized by the multiplicity and instability of its value as a result of the continuous devaluation of the Egyptian pound. In 1986, the government took several measures to liberalize the foreign exchange market, where a flexible exchange rate was applied to all transactions conducted within the scope of approved banks. Then, with the widening gap between exchange rates inside and outside banks, it was decided to establish a free banking market in 1987 to deal in foreign exchange and to allow approved banks operating in Egypt and licensed to deal in Egyptian pounds and foreign currency to buy and sell foreign currency on their account and under their responsibility within the scope of this market, which expanded in 1988 to include all commodity transactions except those that fall within the scope of the Central Bank Complex.

In the early nineties, Egypt began an official agreement with the International Monetary Fund to implement a program for economic reform and structural adjustment. The Central Bank followed a policy of fixing the exchange rate, which did not change during the period (1991-1997) except by only 3%, as the exchange rate reached 3.13 pounds per dollar in 1991, while it reached 3.38 pounds per dollar in 1997. It also allowed for the 1st time the introduction of exchange companies, which helped introduce monetary stability, especially the stability of exchange rates.

During the period (1998-2002), the exchange rate of the Egyptian pound was exposed to a decline in its value by about 20% as a result of internal clashes (the Luxor incident—the recession and depression crisis) and external shocks (the Asian crisis—the events of September 11, 2001), so that the exchange rate reached 3.85 pounds per dollar at the end of the period, which forced the government to adopt a managed float system in January 2001. In 2003, the Central Bank announced the floating of the Egyptian pound and the transition to an exchange rate determined according to the forces of supply and demand in the money market according to the decision issued on January 29, 2003, which led to an increase in the exchange rate of the pound against the dollar from 4.4 pounds/dollar to 5.8 pounds/dollar at the end of 2003 and then to 6.1 pounds/dollar in 2004. In 2005, the Central Bank announced the adoption of an inflation-targeting policy as a pillar of monetary policy, which affected the exchange rate of the Egyptian pound as its value decreased from 6.1 pounds/dollar to 5.8 pounds/dollar. Then, the exchange rate stabilized around 5.61 pounds/dollar on average during the period (2005-2010), and there was only a narrow fluctuation of the pound against the dollar. It remained this way until the January 2011 revolution. The events that followed led to increased pressures on the balance of payments and the exchange rate and a decrease in cash reserves as a result of capital flight and the decline in tourism revenues and the Suez Canal, which led to an increase in the exchange rate of the Egyptian pound to reach 7 pounds per dollar. In light of these pressures, the Central Bank announced in November 2016 the floating of the exchange rate and the reduction of the exchange rate by 40%, which led to a significant decrease in the value of the Egyptian pound, as the exchange rate was about 20 pounds/dollar and dealing in dollars was restricted to the banking system.

By the end of 2019, the Central Bank achieved a relative improvement in the pound's exchange rate to reach 16.77 pounds/dollar, then 15.75 in 2020, then 15.64 pounds/dollar in 2022, and the situation remained stable until March 2022. Since then, the pound has decreased its peak three consecutive times. The first was in March 2022, when the pound's value decreased by 25% from 15.77 pounds/dollar to 19.7 pounds/dollar dollar as shown in Figure 1. The second was in October 2022, when the pound's value decreased by 25% from 19.7 pounds/dollar to 24.7 pounds/dollar. The third was in January 2023, when the pound decreased by 30% from 24.7 pounds/dollar to 32 pounds/dollar. The currency devaluations aimed to boost local production and mitigate the negative repercussions of the COVID-19 pandemic on the Egyptian economy, the exit of indirect foreign investments after raising interest rates globally, and global inflationary pressures. Caused by the Russian-Ukrainian conflict.

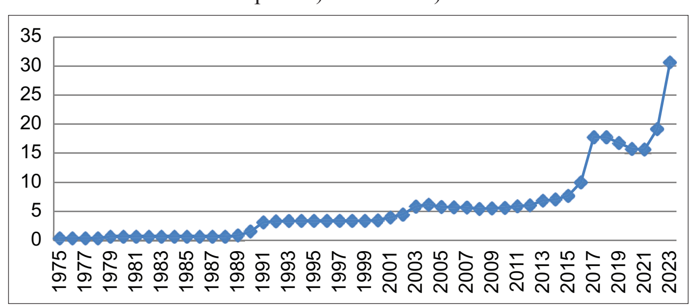
3.2. Analysis of the Development of the Oil Price in Egypt

The price of crude oil reached its highest level during the study period in 2012, recording an average of $111.67/barrel. These positive and negative oil shocks were not only due to economic factors but also political, geological, environmental, regulatory, and technological factors. In the 1960s, the oil price was stable at around $1.8 due to the policies of the Organization of Petroleum Exporting Countries (OPEC), established in 1960. This situation remained until the first oil shock in 1973 for several reasons, the most important of which was the outbreak of the October War. The oil embargo imposed by the Organization of Arab Petroleum Exporting Countries (OAPEC) on Western countries forced Israel to withdraw from Arab lands, which pushed oil prices to rise from $2.5 in 1972 to $11.6 in 1974 as shown in Figure 2. The world economies barely recovered from the first oil shock, and the second came with the outbreak of the Iranian revolution in 1979 when crude oil rose from $14 in 1978 to $36.8 in 1980. In the 1980s, the third oil shock came, sending oil prices plummeting to $14.4 in 1986 as a result of excessive oil production, coinciding with a decline in global demand for oil due to the slowdown in economic activity in industrialized countries at the time.

Oil prices fluctuated up and down until the end of the second millennium, driven by the Iraqi invasion of Kuwait in 1990, the Asian financial crisis in the late 1990s, speculation in futures markets, and fluctuations in the forces of demand and supply. At the beginning of the third millennium, there were steady jumps in oil prices that continued for about a decade, as oil prices surged from $24.4 in 2001 to $97.3 in 2008, an increase of nearly 300%. This is perhaps due in large part to the September 11 attacks that targeted the United States of America in 2001 and the subsequent American invasion of Iraq in 2003, in addition to natural disasters, the most prominent of which was Hurricane Katrina, which struck the United States of America in 2005.

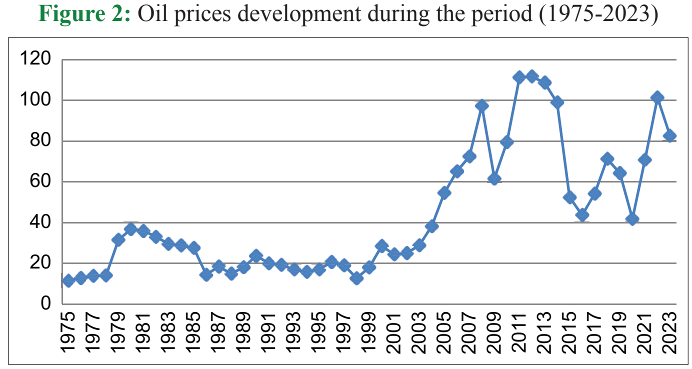
Then came the sharp decline in the price of oil between 2008 and 2009, exceeding 50%, as one of the most important repercussions of the recession that struck the world's economies as a result of the global financial crisis that erupted in the United States of America

Figure 1: Development of the exchange rate in Egypt during the period) 1975-2023)



Source of data: World Bank (WB), World Development Indicators (WDI), 2023

Figure 2: Oil prices development during the period (1975-2023)



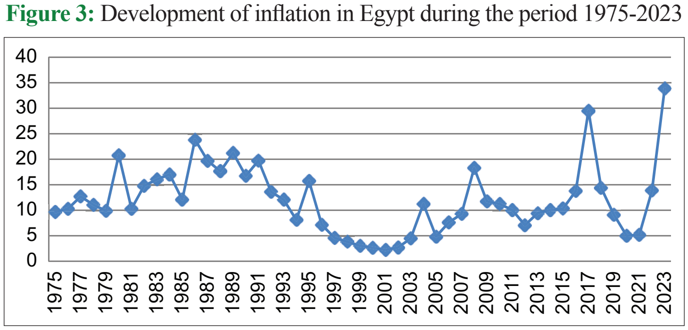
Source of data: World Bank (WB), World Development Indicators (WDI), 2023 in 2008 and extended to include countries whose economies are intertwined with the American economy. Prices then rose again before collapsing in the first decade of the third millennium, as the price of a barrel of oil fell from approximately $111.7 in 2012 to $43.7 in 2016, a decrease of more than half, reflecting the American flooding of global oil markets as the United States increased its oil production by more than 60% between 2011 and 2015. According to data from the Statistical Review of World Energy issued by BP, daily US oil production rose from approximately 8 million barrels in 2011 to approximately 13 million barrels in 2015. Finally, prices began to fluctuate up and down from 2016 until the end of the study period due to several factors, including the COVID-19 pandemic, known as the Corona pandemic, which struck the world from east to west, and the Russian-Ukrainian war.

3.3. Analysis of the Development of the Inflation Rate in Egypt

Figure 3 shows that the inflation rate during the eighties took an upward trend, rising from 10.31% in 1981 to 21.26% in 1989 as a result of the increase in local liquidity that was not commensurate with the growth rates of the gross domestic product, which is due to the increasing reliance by the state on the banking system to cover the general budget deficit, whether through monetary issuance or borrowing and the continuous expansion of bank credit provided by commercial banks. Despite following the credit ceiling policy, this policy was not very effective, as inflation rates continued to increase because inflation is not a purely monetary phenomenon, but rather the factors causing it are multiple and intertwined, which are related to the structural imbalances of the economy and financial and monetary policies.

In the early nineties, there was a gradual decline in the inflation rate as Egypt implemented the economic reform and structural adjustment program. The government followed a contractionary monetary policy accompanied by sterilization policies. It led to a decline in the inflation rate from 16.8% in 1991 to its lowest value of 2.2% in 2002, except for some years. This was achieved by reducing the fiscal deficit rates, the growth rates of money supply and credit directed to the government sector, and taking advantage of international conditions and Egypt's international relations to reduce the burden of external public debt. However, the situation did not last long, as the inflation rate began to rise again to reach 11.27% in 2004 as a result of the decline in the value of the Egyptian pound against the dollar, the increase in local liquidity as a percentage of the gross domestic product, and the rise in global prices of food and petroleum commodities as a result of the Egyptian government floating the pound in early 2003, which led to a 25% decline in the value of the Egyptian pound, and the heavy reliance on imports to meet local demand for most basic commodities.

Figure 3: Development of inflation in Egypt during the period 1975-2023



The inflation rate continued to rise to 9.31% in 2007, then to 18.31% in 2008, due to supply-side shocks resulting from the rise in global food and energy prices following the global financial crisis, the rise in oil prices, and demand pressures, especially in the construction sector, as well as the cancellation of part of the subsidy allocated to petroleum products, which led to higher prices in the transportation sector. As a result of the political events that Egypt was exposed to, the revolutions of January 25, 2011, and June 30, 2013, and the subsequent recession and contraction, the inflation rate gradually decreased after that to reach 7.11% in 2012. Still, the inflation rate rose after that, reaching 29.51% in 2017 due to the liberalization of the exchange rate to become traded in the local market according to the mechanisms of supply and demand, which led to an increase in the prices of the most basic and necessary commodities. Then, it decreased to 13.87% in 2019 and 5.1% in 2020 due to the Central Bank's decisions to contain inflationary pressures. Still, the inflation rate rose again to 13.89% in 2022 due to the slowdown in global economic activity, restrictions on trade movement, the cessation of economic activities, and precautionary measures related to the Corona pandemic. The inflation rate continued to rise to 21.3% in 2023 as a result of supply shocks resulting from the Russian-Ukrainian conflict, which caused food and energy prices to rise, supply chains to be disrupted, and the global investment climate to become unstable, resulting in capital outflows from emerging markets and the subsequent decline in the value of the Egyptian pound against foreign currencies. (Central Bank of Egypt, 2023).

4. METHODOLOGY

This study adopts the non-linear autoregressive distributed lag (NARDL) modeling approach, which was popularized by Shin et al. (2014) based on the linear ARDL model framework proposed by Pesaran et al. (2001) for estimating equilibrium relationships. The NARDL, widely used in literature, uses the positive and negative partial sums of the explanatory variables to account for the short-run and long-run linearity in the model and dynamic multipliers. Following the theoretical exposition and empirical studies, the model for the study is as follows:

$$INF_{2t} = F\,(GDP_t, M_t, EX_t, OP_t)$$

Where INF inflation rate, EX Nominal Exchange Rate, GDP = Gross Domestic Product, M = Money Supply

We take the natural log of all variables to reduce the sharpness of the data. The log-linear model provides empirically accurate, effective outcomes compared to a linear transformation. The main problems in data are multicollinearity and heteroscedasticity. To control these issues, data is converted into a log form. After the log transformation, the model can be rewritten as,

$$Ln\ INF_t = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnM_t + \beta_3 LnEX_t + \beta_4 LnOP_t + \varepsilon_t \quad (1)$$

Where t shows the analysis period (1990-2017), and β refers to coefficients β_1, β_2, β_3, and β_4, which are the coefficients of GDP, M, EX, and OP, and ε_t is the error term.

The previous relationship can be expressed in its non-linear form by separating the oil price and local liquidity variables into two components: one expressing positive changes and the other expressing negative changes:

$$Ln\ INF_t = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnM_t + \beta_3 LnEX_t^+ + \beta_4 LnEX_t^- + \beta_5 LnOP_t^+ + \beta_6 LnOP_t^- + \varepsilon_t \quad (2)$$

Where EX_t^+, EX_t^-, OP_t^+, OP_t^-, are the partial sums of the positive and negative changes in the logarithm of exchange rate and oil price, and can be obtained as follows:

$$LnEX_t^+ = \sum_{j=1}^{t} \Delta LnEX_t^+ = \sum_{j=1}^{t} \max(\Delta LnEX_j, 0) \quad (3)$$

$$LnEX_t^- = \sum_{j=1}^{t} \Delta LnEX_t^- = \sum_{j=1}^{t} \min(\Delta LnEX_j, 0) \quad (4)$$

$$LnOP_t^+ = \sum_{j=1}^{t} \Delta LnOP_t^+ = \sum_{j=1}^{t} \max(\Delta LnOP_j, 0) \quad (5)$$

$$LnOP_t^- = \sum_{j=1}^{t} \Delta LnOP_t^- = \sum_{j=1}^{t} \min(\Delta LnOP_j, 0) \quad (6)$$

Eq. (2) can be written in an unrestricted error correction form as proposed by Pesaran et al. (2001) and Shin et al. (2014) as:

$$\begin{aligned} \Delta LnINF_t &= \beta_0 + \sum_{i=1}^{q} \beta_0 \Delta LnINF_{t-i} + \\ &\sum_{i=0}^{m} \beta_{2i} \Delta LnGDP_{t-i} + \sum_{i=0}^{q} \beta_{3i} \Delta LnM_{t-i} \\ &+ \sum_{i=0}^{p} \beta_{4i}^+ \Delta LnEX_{t-i}^+ + \sum_{i=0}^{r} \beta_{5i}^- \Delta LEX_{t-i}^- + \\ &\sum_{i=0}^{s} \beta_{6i}^+ \Delta LnOP_{t-i}^+ + \sum_{i=0}^{l} \beta_{7i}^- \Delta LnOP_{t-i}^- + \\ &\lambda_{1i} Ln\ INF_{t-1} + \lambda_{2i} LnGDP_{t-1} + \lambda_{3i} LnM_{t-1} \\ &+ \lambda_{4i}^+ LnEX_{t-1}^+ + \lambda_{5i}^- LnEX_{t-1}^- + \\ &\lambda_{6i}^+ LnOP_{t-1}^+ + \lambda_{7i}^- LnOP_{t-1}^- + \varepsilon_t \end{aligned} \quad (7)$$

In which Δ is a first difference, β_0 It is the constant of the function, q,m,n,p,r,s,l The optimal number of time lags for each variable, β_{1i}, β_{2i}, β_{3i}, β_{4i}, β_{5i}, β_{6i}, β_{7i} Parameters represent short term, While λ_1, λ_2, λ_3, λ_4, λ_5, λ_6, λ_7 represent the long-run parameters, εt represents the random error term.

The previous unrestricted error correction model can be estimated through several steps as follows: First, the stability of the variables included in the model is detected, and their integration order is determined through the unit root test. The Augmented Dickey-Fuller (ADF) test is used (Dickey and Fuller, 1979). The main goal of the unit root test is to ensure that there is no variable with an integration order of I (2).

Second, the optimal number of lags for all level variables is selected using the appropriate information criteria, mainly the Akaike information criterion (AIC) and Schwartz Information Criterion (SIC).

Third, the Bounds testing approach developed by Pesaran et al. (2001) and Shin et al. (2014) was used to detect a long-run relationship between the model variables, where the following hypothesis is tested:

H_0: $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = \lambda_7$

H_1: $\lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \neq \lambda_7$

After obtaining the F-statistic value, it is compared with the critical values proposed by Pesaran et al. (2001). Suppose the F-statistic value falls above the upper-bound critical value at a certain significance level. In that case, the null hypothesis is rejected, and the alternative hypothesis, which states a long-term relationship between the model variables, is accepted.

Fourth, estimating the Error Correction Model (ECM) to ensure joint integration between the study variables by examining the negativity and significance of the Error Correction Term Coefficient (ECT), whose value expresses the speed of adjustment as follows:

$$\begin{aligned} \Delta LnINF_t &= \beta_0 + \sum_{i=1}^{q} \beta_{1i} \Delta LnINF_{2t-i} + \\ &\sum_{i=0}^{m} \beta_{3i} \Delta LnGDP_{t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta LnM_{t-i} \\ &+ \sum_{i=0}^{p} \beta_{5i}^+ \Delta LnEX_{t-i}^+ + \sum_{i=0}^{r} \beta_{6i}^- \Delta LEX_{t-i}^{\mp} \\ &\sum_{i=0}^{s} \beta_{7i}^+ \Delta LnOP_{t-i}^+ + \sum_{i=0}^{l} \beta_{8i}^- \Delta LnOP_{t-i}^- \varphi ECT_{t-i} + \varepsilon_t \end{aligned}$$

Fifth, as soon as the long-run equilibrium relation exists among variables, we can estimate the long-run asymmetric impact of exchange rate and oil price on inflation. The short-run asymmetric impact of exchange rate and oil price on inflation was also assessed by deriving the cumulative dynamic multiplier of a 1% change in EX_t^+, EX_t^-, OP_t^+, OP_t^-, respectively as:

$$B_a^+ = \sum_{j=0}^{a} \frac{pINF_{t+i}}{pEX_t^+} = B_a^- = \sum_{j=0}^{a} \frac{pINF_{t+i}}{pEX_t^-}, a = 1, 2, 3, ...$$

$$B_a^+ = \sum_{j=0}^{a} \frac{pINF_{t+i}}{\varphi OP_t^+} = B_a^- = \sum_{j=0}^{a} \frac{pINF_{t+i}}{\varphi OP_t^-}, a = 1, 2, 3, ...$$

Note that as: $a \rightarrow \infty$, $B_a^- \rightarrow \beta_3$, $B_a^- \rightarrow \beta_4$, $B_a^+ \rightarrow \beta_5$, $B_a^- \rightarrow \beta_6$

Finally, the model must undergo several statistical checks, such as autocorrelation, heteroscedasticity, normality, and stability tests to ascertain their statistical reliability.

5. RESULTS AND DISCUSSION

5.1. Data

This study used annual data from 1975 to 2023. The data were collected from the World Bank and World Development Indicators. The price of crude oil was obtained from the Statistical Review of World Energy data issued by BP.

5.2. Descriptive Statistics and Stationarity Tests

The results of the descriptive statistics of the variables are given in Table 1. We note that standard deviation values Std. Dev of the model variables are noted to be low, reflecting the degree of concentration of the observation values of these variables around their arithmetic mean.

The results of the correlation matrix between the study variables shown in Table 2 showed that the relationship between the study variables is weak, where the value of the correlation coefficient is less than 50%, except for the relationship between the two variables GDP and EX is strong, where the value of the correlation coefficient is 0.96. There are positive relationships between M, OP, and INF and negative relationships between GDP, EX, and INF.

Tables 1: Descriptive stats

Descriptive statistics	INF	GDP	M	EX	OP
Mean	2.320	25.807	4.368	1.106	3.526
Median	2.404	25.852	4.409	1.222	3.386
Maximum	3.522	26.877	4.586	3.421	4.715
Minimum	0.819	24.431	3.821	−0.938	2.444
Standard deviation	0.625	0.679	0.181	1.223	0.695
Skewness	−0.595	−0.236	−1.656	−0.199	0.237
Kurtosis	2.923	2.007	5.461	1.970	1.778
Observations	49	49	49	49	49

Source: Authors own calculations using EViews

Table 2: Correlation matrix

Variable	INF	GDP	M	EX	OP
INF	1				
GDP	−0.153	1			
M	0.027	0.567	1		
EX	−0.182	0.961	0.532	1	
OP	0.069	0.758	0.340	0.681	1

Source: Authors own calculations using EViews

5.3. Unit Root Tests

The next step is to test the stationarity of variables to ensure that no variable in the system is I(2) because the NARDL bounds-testing technique requires that the variables be I(0) or I(1) to examine the cointegration among the variables. The NARDL model is invalid for the occurrence of the variable being I(2) because the F statistics of the joint test are calculated on the premise of the variables being I(0) or I(1). For this purpose, in this study, we used the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methods for stationarity testing. In addition, Table 3 presents the results of stationarity tests.

As can be seen from Table 3, the level forms of all variables are found to be non-stationary, except for Ln M via ADF and PP tests, while it is stationary at the first difference form the 1%. The results of the unit-root testing confirm that no variable is I(2). Therefore, all the variables can be included in a NARDL model without any problems.

5.4. Determination of NARDL Optimal Lag Order

In addition, a proper lag-order selection of the equation is a prerequisite to further investigating the relationship between exchange rate, oil price, and inflation by applying the NARDL method. The ARDL model allows the selection of different lags for dependent and independent variables. Usually, the optimal lag order is determined by one or more "information criteria": Akaike information criterion (AIC), Schwarz Criteria (SC), and Hannan-Quinn criterion (HQ). These criteria are based on a high log-likelihood value. In this paper, the (AIC) values are adopted to determine the optimal lag order of the NARDL model. The lag order of the NARDL (q, m, n, p, r, s, l) model can be seen in Figure 4, which shows the NARDL (2,1,3,1,3).

5.5. Cointegration Test

Based on the Bounds testing approach, Table 4 shows the cointegration test results.

The results reveal that the F-statistic value 6.015 exceeds the critical upper bounds at 1%, 5%, and 10% significance levels. Therefore, the null hypothesis (H_0) of no long-term relationship is rejected, and the alternative hypothesis (H_1) is accepted. Thus, there is evidence of cointegration based on the bounds test results, which show that non-linear cointegration exists

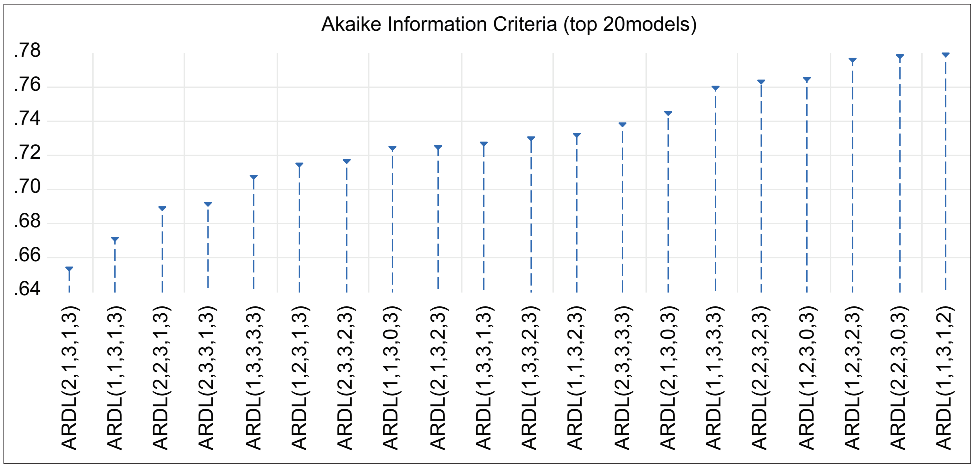
Table 3: Unit-root test results

Variable	The level				First difference				Order of integration
	ADF		PP		ADF		PP		
	Contant	Trend	Contant	Trend	Contant	Trend	Contant	Trend	
INF_t	−2.339 (0.164)	−2.221 (0.467)	−2.404 (0.145)	−2.290 (0.430)	−7.243*** (0.000)	−7.214*** (0.000)	−7.374*** (0.000)	−7.361*** (0.000)	I (1)
GDP_t	−1.628 (0.460)	−2.942 (0.159)	−2.900* (0.052)	−4.546*** (0.003)	−5.213*** (0.001)	−5.283*** (0.000)	−5.213*** (0.000)	−5.283*** (0.000)	I (1)
M_t	−3.903*** (0.004)	−3.557*** (0.044)	−3.208** (0.025)	−3.789** (0.020)	−5.240*** (0.000)	−5.448*** (0.000)	−5.240*** (0.000)	−5.418*** (0.000)	I (0)
EX_t	0.420 (0.896)	−3.111 (0.115)	−0.277 (0.920)	−2.292 (0.429)	−4.386*** (0.001)	−4.320*** (0.006)	−3.787*** (0.005)	−3.724** (0.030)	I (1)
OP_t	1.591 (0.479)	−2.264 (0.444)	−1.622 (0.463)	−2.355 (0.397)	−5.771*** (0.000)	−−6.525*** (0.000)	−6.615*** (0.000)	−6.531*** (0.000)	I (1)

***, ** and * denote significant at 1%, 5% and 10%, respectively

Source: Authors own calculations using EViews

Figure 4: Determining the optimal number of time lag periods according to the (AIC) analysis



Source: Authors own calculations using EViews

Table 4: Bounds test for cointegration

Critical value			Value (F-statistic)
Significant	Lower bound Value I (0)	Upper bound Value I (1)	
10%	2.49	3.81	6.015
5%	2.81	3.76	
1%	3.50	4.63	

Source: Authors own calculations using EViews

Table 5: Coefficient asymmetric test

Variable	Statistic	Value	Prob.
Long run			
EX	F-statistic	7.207	0.013***
OP	F-statistic	0.089	0.767
Short run			
EX	F-statistic	16.070	0.000***
OP	F-statistic	1.748	0.199

***, **and *denote significant at 1%, 5% and 10%, respectively

Source: Authors own calculations using EViews

among the variables. This fulfills the necessary conditions for a non-linear ARDL model. We can now estimate the impact of negative and positive Exchange rates and oil price changes on inflation in Egypt.

5.6. Asymmetry Tests

Table 5 demonstrates that short- and long-run exchange rates and oil prices are asymmetric. The exchange rate has an asymmetric effect on the inflation rate in the long and short run, as it is shown to be <0.05, which means rejecting the null hypothesis that there is symmetry in the long run. Regarding the oil price, the null hypothesis can be accepted in both the long and short run, and thus, the effect of the oil price on inflation is the same in both the long and short run.

5.7. NARDL Model Estimwation Results

Table 6 shows the estimation results of the non-linear distributed gap autoregressive model (NARDL), where the first part of the table shows the long-term outputs and the second part shows the short-term outputs. The estimated long-run coefficients, presented in Panel (A) of Table 6, show that the GDP negatively influences

Table 6: Results of NARDL

Variable	Coefficient	Standard deviation	t-Statistic	Prob.*
(A) Long run				
GDP_t	−13.899***	3.745	−3.710	0.000
M_t	7.927***	1.686	4.700	0.000
EX_t^+	−0.665*	0.330	−2.011	0.051
EX_t^-	−12.615***	3.790	−3.328	0.001
OP_t^+	0.100	0.614	0.163	0.870
OP_t^-	0.409	0.498	0.821	0.416
$TREND$	0.627***	0.172	3.643	0.000
(B) Short run				
ΔINF_{t-1}	−0.180*	0.096	−1.871	0.071
ΔGDP	−4.233***	−2.531	−1.672	0.014
ΔM_t	1.163**	0.545	2.128	0.041
ΔM_{t-1}	−2.982***	0.878	−3.395	0.001
ΔM_{t-2}	−3.172***	0.832	−3.809	0.000
ΔEX_t^+	−0.110	0.273	−0.404	0.688
ΔEX_{t-1}^+	1.075***	0.275	3.896	0.000
ΔEX_{t-2}^+	−0.161	0.268	−0.599	0.553
ΔEX_t^-	6.119**	2.821	2.168	0.038
ΔEX_{t-1}^-	16.705***	0.275	3.896	0.000
ΔEX_{t-2}^-	10.116***	3.331	3.036	0.004
ΔOP_t^+	0.660**	0.296	2.226	0.033
ΔOP_t^-	−0.509*	0.283	−1.801	0.081
ECT_{t-1}	−0.831***	0.104	−7.923	0.000
C	259.44***	32.748	7.922	0.000
R-Squared	0.81			
Adjusted R-Squared	0.72			

***, ** and *denote significant at 1%, 5% and 10%, respectively.
Source: Authors own calculations using EViews.

Table 7 : Diagnostic tests

Test	Statistics	Value	Prob.
Normally	Jarque - Bera	4.935	0.0847
Serial Correlation	F-Statistic	0.5164	0.6040
Heteroscedasticity	F-statistic	0.6324	0.8424
Stability test	F-statistic	0.1347	0.7171

Source: Authors own calculations using EViews

inflation in the long and short run. These findings are consistent with the Keynesian theory since the increase in real production or supply of goods and services, other factors being constant, is expected to alleviate inflation. While M has a positive on inflation in the long and short run, his finding is consistent with the economic theory. An increase in the money supply reduces the interest rate. Therefore, more investment and consumption are expected, which results in more aggregate expenditure. Accordingly, more aggregate demand is generated, and higher inflation is driven. Thus, money supply affects inflation mainly through the demand side.

Regarding the asymmetric relationship between inflation and exchange rate, positive and negative exchange rate shocks have a significant and negative impact on the inflation rate. In contrast, positive and negative oil price shocks do not significantly impact the inflation rate.

For the short-run exchange rate, it is clear from the table that a positive shock has a negative and insignificant effect on the inflation rate, while a negative shock has a significant and positive effect on the inflation rate. On the other hand, the positive shock of oil prices in the short run has a positive and significant effect on the inflation rate, while the negative shock has a significant and negative effect on the inflation rate.

5.8. Dynamic Multipliers

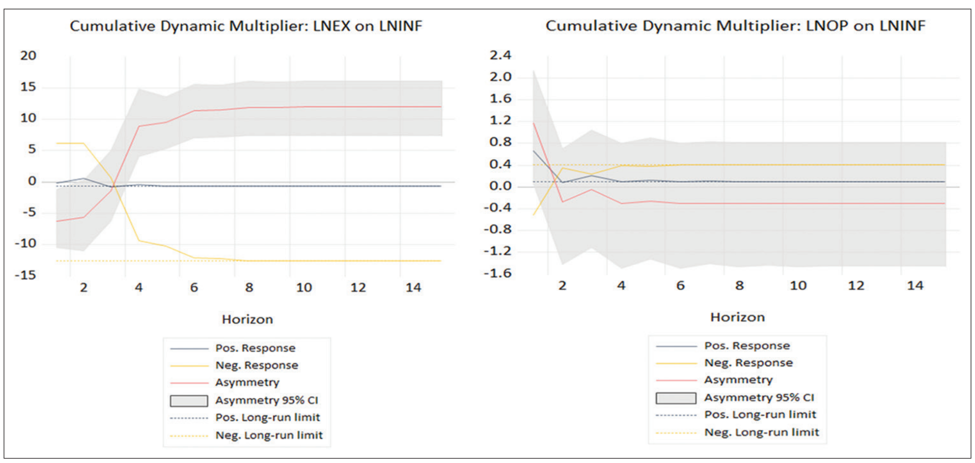
The dynamic multipliers show the patterns of dynamic asymmetric inflation adjustments from its initial equilibrium to the new steady state in the long run, following a negative or positive shock in the exchange rate or oil price.

Figure 5 shows that positive and negative exchange rate shocks have a negative long-term effect on inflation. In contrast, positive and negative oil price shocks have a positive long-term effect on inflation. In general, the dynamic multipliers show that the long-term coefficient of negative shocks in the exchange rate and oil price is higher than that of a positive shock.

5.9. Diagnostic Tests of Model

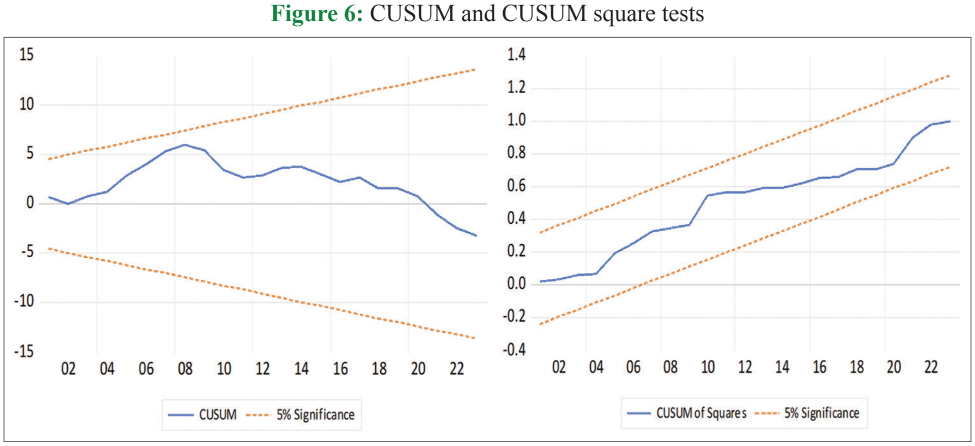
One of the most crucial assumptions in the NARDL bounds testing methodology is that the NARDL model errors must be serially independent, normally distributed, and homoscedastic. Also, the functional form must be checked. The diagnostic tests

Figure 5. Dynamic multipliers



Source: Authors own calculations using EViews

Figure 6: CUSUM and CUSUM square tests



Source: Authors own calculations using EViews

were carried out to examine the validity of the estimated results (Table 7). A serial correlation test via a Breusch-Godfrey serial correlation LM test, a normality test via a Jarque-Bera test, a heteroskedasticity test via a White test, and a functional form test via a Ramsay reset test.

In the end, we also conducted CUSUM and CUSUM of squares to examine the stability of the NARDL model (Figure 6). CUSUM and CUSUM of squares indicate that the coefficients are stable at a 5% significance level throughout the sample period. Because the anticipated line is well inside the critical boundaries at the 5% significance level, this indicates that the NARDL model is stable.

6. CONCLUSION AND POLICY IMPLICATIONS

This study examined the asymmetric effect of exchange rate and oil prices on inflation in Egypt from 1975 to 2023 using the nonlinear ARDL (NARDL) model. The linear formulation lacks the power to detect asymmetric behavior in an exchange rate and oil price, so this study further estimated the effect of the exchange rate and oil price on inflation using a nonlinear formulation by decomposing the exchange rate and oil price into positive and negative changes. In the nonlinear model, the long-run estimates imply that positive changes in exchange rate have less effect on inflation than negative changes in the long and short run. Contrarily, positive changes in oil prices have a greater effect on inflation than negative changes in oil prices in the short run. At the same time, the long-run estimates imply that positive changes in oil prices have less effect on inflation than negative changes in oil prices. Contrarily, positive changes in oil prices affect inflation more significantly than negative changes in the short run. Also, the long-run result shows a negative relation between GDP and inflation. Contrarily, there is a positive relation between money supply and inflation in the long and short run.

From the result of the study, it is pretty clear that the main triggering factor of inflation in Egypt is instability in the exchange rate, oil prices, and money supply. Therefore, following a contractionary monetary policy is important to tighten the stock of money and avoid instability in the exchange rate market. Moreover, to curb inflation, the Central Bank of Egypt must ensure a stable exchange rate by attracting foreign private investment through macroeconomic policies incentivizing foreign investors.

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