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The asymmetric relationship between oil price shocks and macroeconomic fluctuation in Tanzania: A multivariate time series model approach

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Abstract
As a developing oil importer, Tanzania relies heavily on crude oil imports for the majority of its industrial and socioeconomic operations. Hence, verifying the link between oil price shocks and macroeconomic variables is critical for effective policy formulation and investment decisions. This paper examines the asymmetric relationship between oil price shocks and macroeconomic fluctuations using the linear and nonlinear autoregressive distributed lag models for Tanzania from 1989 to 2020 data set. Oil price and macroeconomic indicators are not cointegrated according to the results of the asymmetric autoregressive distributed lag model (NARDL), which indicates a specification short-run relationship between oil price shocks and macroeconomic indicators. Meanwhile, the analysis shows that the fitted linear ARDL (1, 0, 0) and nonlinear ARDL (1, 0, 0, 0, 1) time series models are significant, which indicate that there is a linear and assymetric relationship between oil price shocks and macroeconomic variables. The linear model (ARDL) shows that the lag 1 of oil price has a positive significant effect while the asymmetric model (NARDL) shows that the negative change in the inflation rate of Tanzania has a negative significant effect on oil price shock.

Keywords: Oil price, GDP, macroeconomic fluctuation, linear ARDL, NARDL, inflation

Introduction

Oil is a valuable natural resource that all countries desire, and even those who already possess it desire more. As a result, people are willing to go to great lengths to learn more about it. Oil has risen in prominence as a commodity in recent years, with a significant portion of the economy reliant on it (Barsky and Kilian, 2004) [1]. Consequently, oil prices affect almost every economy (Blanchard and Gali, 2007) [5]. Furthermore, oil is used to transport goods and services, its price has an impact on the entire economy (Bhattacharya and Bhattacharya, 2001) [4]. The price of goods and services tends to rise when the price of oil rises. Moreover when gasoline and diesel prices rise, it affects everyone which causes inflation (Bhattacharya and Bhattacharya, 2001) [4]. Inflation has a negative impact on a country's economy (Bernanke *et al.*, 1997) [3]. Firms are affected both directly and indirectly as input costs rise and client demand falls because crude oil is used in the production of a wide range of goods and services and transportation in a wide range of industries (IMF, 2020) [17].

This has encouraged policymakers and the global economy to explore how oil shocks affect economic activity and the policy implications for socio-economic growth. Practically, in every country, energy is a crucial component of industrial production and socioeconomic development. Energy constraints or depletion, particularly of oil, regularly grinds the economy to a halt. Crude oil prices are commonly criticized for affecting consumer and business spending decisions, as well as the overall economy. Prices of crude oil have fluctuated significantly over the last few decades, reaching $84 per barrel in October 2021 (Statista, 2022). Since the 1974 Arab oil embargo, which generated the first oil shock, numerous studies have sought to demonstrate a causal relationship between oil price shocks and macroeconomic activity (Barsky and Kilian, 2004) [1]. Hamilton (1983) [13], a pioneer in this discipline, has studied oil and macroeconomics since World War II. His findings indicate that big oil price shocks preceded seven of the eight recessions in the United States since 1945, as well as a negative association between oil price shocks and economic activity.

Hamilton's work attracted a large number of early scholars. Numerous of their studies, the majority of which examined the causal association between oil price shocks and global recession, bolstered the argument that an unexpected spike in oil prices harms output (Rasche and Tatom, 1981; Hamilton, 2008) [25, 14]. Despite the inability of early researchers to establish causation, this historical evidence and findings were largely accepted until subsequent studies cast doubt on the utility of researching oil price shocks and their impact on economic activity (Hooker 2002; Hamilton, 2006) [16]. Their concerns have rekindled debate over the relationship between oil prices and the macroeconomic environment. According to recent research, the negative association between rising oil prices and output has ceased to exist. According to these studies, the negative association peaked during the financial crisis of 2007-2009 and subsequently diminished as the global economic downturn ended (Hooker, 2002; Nakov and Pescatori, 2010) [16, 21]. Numerous explanations have been advanced for why the relationship ended: First, the bulk of economies' monetary policies have shifted, with a renewed focus on maintaining a steady inflation rate. Second, the real pay rigidity is decreasing, which helps to smooth out the price-output trade-off. Thirdly, the majority of economies are reducing their dependency on oil as a percentage of Gross Domestic Product (GDP) while boosting their energy efficiency. Fourth, the factor that determine the price of oil have weakened. Finally, energy conservation measures, alternative energy development, and technological innovation are growing in importance among the world's largest oil-importing economies. Despite the critical role of energy in industrial production and societal growth, numerous studies have examined exclusively the causal relationship between oil price shocks and output. On the other hand, this study will contribute to the body of knowledge by examining the relationship between oil price shocks and macroeconomic indices. Additionally, this research is significant since the asymmetric relationship between oil price shocks and macroeconomic fluctuations has not been investigated in Tanzania by using the more reliable estimation techniques. It will be interesting to observe whether the findings of asymmetric effects and the diminished impact of oil price shocks on output in sophisticated oil-importing economies apply to Tanzania.

The following is the outline of the paper structure: the next section reviews the empirical literature on the existence of a relationship between oil price and each of the other two variables; inflation and GDP. The data and methodology parts are presented in Section 3, while empirical results and conclusions are presented in Sections 4 and 5, respectively.

Literature review

Crude oil remains a significant commodity and oil market events impact global economic and political growth, despite a long-term fall in global oil production (Fengbo Zhang, 2012) [10]. As the world's primary source of energy, crude oil is vital to economic growth and, in the long run, affects GDP (Hamilton, 2009) [15]. If the Tanzanian crude oil market was linked to the global crude oil market, other macroeconomic parameters in Tanzania would be affected by the international crude oil price through the domestic crude oil price (Song Zheng; Chang-Tai Hsieh, 2015) [29]. The rapid growth of Tanzania's economy has necessitated an increase in the demand for crude oil (Joyce Ho, 2016) [19]. This, however, shows that Tanzania's GDP and crude oil prices are not in synchronize. In 2020, Tanzania's GDP was expected to reach 62.41 billion USD, according to preliminary forecasts (World Bank, 2021) [12]. Tanzania has been a major producer and exporter of natural gas for more than half a century. Songo Songo Island (Lindi Region) was the first natural gas discovery in Tanzania, while Mnazi Bay was the second (Mtwara Region). Tanzania has a total of 842 kilometers of gas transmission pipes, with 58 kilometers in Dar es Salaam being used for industrial customers. According to the data provided by the Ministry of Energy in December 2017, the found natural gas reserves are 57.54 trillion standard cubic feet (TCF). It's been a while since Tanzania has had a commercial oil discovery, and the country doesn't produce crude oil. There are approximately 35,000 barrels of refined oil products imported into Tanzania per day.

To put it simply, an increase in crude oil prices of $10 has been predicted by the International Monetary Fund, the World Bank, and the Organization for Economic Cooperation and Development. There is a close correlation between worldwide economic growth and global oil demand. A large portion of crude oil's value is influenced by the amount of crude oil being produced. Oil price shocks, mostly produced by OPEC countries, are widely considered to have been the most important economic event since World War II, according to many experts. Oil prices have been linked to major economic indicators in the past, but this issue was original and academics asked questions such as the impact of oil shocks numerically and their linkage with government policy to anticipate the best tool to deal with rising oil costs.

Hooker (2002) [16] separates his study period from 1962 to 2000 into two subperiods to analyze the link between oil prices and inflation due to a structural break at the end of 1980. In the first period from 1962 to 1980, he found that oil prices have a major impact on inflation, but not in the second subperiod from 1981 to 2000. Trehan (2005) [27] backs up Hooker's findings by investigating the same topic and coming to the same conclusions. Roger (2005) [27] conducted a study on several European countries and discovered a short-run tradeoff between GDP and inflation, emphasizing the relevance of oil prices for the European region, at least in the short term. Bermingham (2008) [2] also investigated the influence of rising oil prices on inflation in Ireland's small open economy and the results revealed that rising oil price has a significant effect on inflation. In the Euro area, Jacquinot *et al*. (2009) [18] found that oil price changes are an important element in forecasting inflation in the short term, although the influence is complex in the long run. Furthermore, Castillo *et al*. (2010) [6] indicated that rising oil price volatility can contribute to increased inflation.

In regard to the impact of oil prices, another common macroeconomic indicator that occurs in the literature is GDP. Korhan *et al*. (2015) [31] conducted a study to examine the relationship between GDP and oil prices in Turkey. Johnson's cointegration test shows that there is an existing long-run relationship between GDP and oil price. In addition, Glasure and Lee (1998) [11] establish a strong positive relationship between GDP and oil prices in North Korea. Kim and Willet (2000) [20], establish a similar association between oil price and GDP in OECD countries.

Based on the literature review, the oil price is a significant input component in a variety of econometric models. However, the literature review shows conflicting results because there is no consensus reached on the relationship between oil price and macroeconomic variables due to the dissimilar methodologies, different study periods, and different sets of study variables. For example, a study conducted by Barsky and Kilian (2004) [1] established a unidirectional relationship between oil price and macroeconomic indicator, while other scholars such as Kim and Willet (2000) [20], Trehan (2005) [30], and Ewing and Thompson (2007) [9], suggest that the oil price has an impact on macroeconomic indicators. Therefore, the interrelationship between oil price and macroeconomic variables needs fresh inquiry.

This study examines the asymmetric link between oil price shocks and macroeconomic variation in Tanzania to add robustness and depth to earlier research. It is also an attempt to close the research gap by contributing to the scant literature on developing oil-importing countries in general, and Tanzania in particular.

Data and methodology

Data

The data used for this study is annual time series data from 1989 to 2020 on oil price and macroeconomic variables in Tanzania extracted from world development indicator (WDI) and the BP Statistical review of the world energy databases. The web links are as follows: https://databank.worldbank.org/source/world-development-indicators and, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf. The datasets used or analyzed during this study are also available from the corresponding author on reasonable request. This study utilized two macroeconomic variables, namely, GDP and inflation, based on the data availability that are adequately long. The Consumer Price index (CPI) of the United States is used to deflate the price of Brent oil in US dollars per barrel. The real GDP per capita (US$ 2010 constant) is used to measure the GDP. The Brent oil price data were obtained from Energy and Water Utilities Regulatory Authority (EWURA) in Tanzania while GDP and inflation were obtained from Bank of Tanzania (BOT).

Methodology

Unit root test

The unit root test, also known as the stationarity test, indicates the presence of a unit root if the series lacks stationarity and may lead to spurious results and the absence of a unit root if the series does have stationarity. To avoid the problem of spurious results, the unit root test is accomplished through the use of the augmented Dickey-Fuller test (ADF). The hypothesis to accomplish the unit test can be stated as:

H_0: there is a presence of a unit root (series is not stationary) vs H_a: there is no unit root (the series is stationary). The ADF test can be presented mathematically as:

$$\Delta Y_t = \theta + \gamma Y_{t-1} + \sum_{i=1}^{p} \beta_i Y_{t-i} + \omega_t \quad (1)$$

Where, θ is a constant, γ is the coefficient of process root, β_i coefficient in time tendency, p is the lag order and ω_t is the disturbance (error) term.

ARDL and bound test

ARDL is a linear time series model that is only suitable when the series of variables of interest are having a combination of I(0) and I (1) orders of integration. When any of the variables of interest are integrated of order two, I (2), then ARDL is not suitable. It is a good time series model as it can specify for short-run relationships when there is no cointegration and vector error correction (VECM) or unrestricted error correction model (UECM) for long-run relationship when there is a cointegration using a bound test (Pesaran, Shin Y, & Smith R, 2001) [28, 23].

The hypothesis for the bound test for cointegration can be set as:

$H_0: \beta_i = 0$ vs $H_a: \beta_i \neq 0$ $(where\ i = 1, 2, 3)$ and the decision rule states that reject the null hypothesis if F-value > I(1) bound implying that there is cointegration otherwise there is no cointegration.

The Linear ARDL model can be generally specified as:

$$Y_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta Y_{t-1} + \sum_{i=1}^{q} \beta_{2i} \Delta X_{1t-i} + \cdots \sum_{i=0}^{r} \beta_{ki}\, \Delta X_{kt-i} + \varepsilon_t \quad (2)$$

β_0 is the constant and Δ is the difference operator.

$\beta_{1i}$is the coefficient of order p lag of ΔY_{t-1}, β_{2i} is the coefficient of order q lag of X_{1t-i}.

ε_t is the error term. Y_t is the dependent variable (Oil price), Y_{t-1} the lag of the dependent variable, while the independent variable (Macroeconomic variable) is X_t and X_{t-i} is the lag of the independent variable.

NARDL and bound test

To capture the asymmetric relationship (non-linear relationship) between oil price, GDP, and inflation, this study utilized non-linear autoregressive distributed lag (NARDL). NARDL helps to look at the effect of regressor or exogenous variables, positive change and negative change effect of oil price on the microeconomic indices. The study conducted by Pesaran *et al*. (2001) [12] found that the NARDL model works better in small samples and may be used whether the variables are integrated at order one or zero, or a combination of the two. Furthermore, Nusair (2016) [22] pointed out that NARDL approach capture short-run model and long-run relationships if the variables are cointegrated, but it is ineffective when the variables are cointegrated at order 2.

The hypothesis for the bound test for cointegration can be set as:

Ho: $\beta_i = 0$ vs Ha: $\beta_i \neq 0$ and the decision rule states that reject the null hypothesis if F-value > I (1) bound and that means there is cointegration otherwise there is no cointegration.

And the NARDL can be specified as

$$Y_t = C_0 + C_{1t} + \sum \emptyset_i Y_{t-I} + \sum \beta_i X_{t-I} + C1t^{+} + C1t^{-} + \sum \emptyset_i Y_{t-I}^{+} + \sum \emptyset_i Y_{t-I}^{-} + \sum \beta_i X_{t-I}^{+} + \sum \beta_i X_{t-I}^{-} + \varepsilon_t \quad (3)$$

Result and Interpretation

Table 1: Descriptive statistics

	OBS	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
GDP	32	24.791	17.540	62.410	4.258	19.333	0.618	1.968	3.458
INFL	32	12.436	7.5600	37.900	3.000	9.9192	1.160	3.271	7.275
OIL_PRICE	32	59.509	56.685	99.450	23.120	22.987	0.279	2.198	1.271

Source: Author's calculation

The result of the descriptive statistics in Table 1 for GDP (M=24.79, SD = 19.33) indicates that the average Gross domestic product of Tanzania is about 24.79 billion us dollars with the variability of 19.33 billion us dollars from the mean.

Inflation (M =12.44, SD = 9.92) implies that on average the inflation rate of Tanzania is about 12.44% with a variability of about 9.92%. In the same vein, Oil price (M = 59.51, 22.99) implies that on average the oil price is about US $59.51 with the variability of about US $23. Meanwhile, the Jarque-Bera probability shows that $P>0.01$ for inflation and $P>0.05$ for both gross domestic product and oil price, which indicate that GDP, inflation, and oil price are normally distributed.

Table 2: Test for unit root

Variables	Test Statistic	P-values	Order	Lag
Δ Oil Price	-5.62	0.000*	I (1)	(1)
Δ GDP	-3.94	0.005*	I (1)	(0)
Δ Inflation	-3.55	0.014**	I (1)	(2)

Where ** and * are asterisks which represent 5% and 1% significant levels, respectively

Table 2 shows the unit root test results using ADF. The test result show that the differencing of oil price and GDP are integrated of order one, I(1) at 1% significant level while the differencing of inflation is also integrated of order one, I(1) but at 5% significant level. This indicates the variables of interest for this study satisfy the condition for the choice of linear and nonlinear ARDL since all are integrated of order 1. Meanwhile, the lag value of differenced oil price is 1, the lag value of the differenced GDP is zero, and the lag value of the differenced inflation is 2.

Table 3: ARDL Results

Selected Model: ARDL (1, 0, 0)				
Dependent Variable: Oil_Price				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
OIL_PRICE(-1)	0.365175	0.176353	2.070704	0.0481
*GDP	-0.3078	0.249798	-1.2322	0.2285
INFLATION	-0.7388	0.528253	-1.39858	0.1733
C	55.70721	19.31837	2.88364	0.0076
F-statistic	4.186721	Durbin-Watson stat		1.855651
Prob (F-statistic)	0.01479			

The above linear ARDL ($P<0.05$) indicates that the ARDL model is statistically significant at 0.05 level, which indicates a linear relationship between oil price, first lag of oil price, GDP, and inflation. Meanwhile, lag 1 of oil price ($P< 0.05$, $\beta = 0.365$) indicates a positive significant impact on the oil price.

Table 4: ARDL (1, 0, 0) Model Bound Test

AIC Criteria Model	(1, 0, 0)		
F statistic	4.406376		
Critical Value			
Significance	1%	5%	10%
Critical Value I(0)	5.15	3.79	3.17
Critical Value I(I)	6.36	4.85	4.14
Diagnostic Test			
Breusch-Godfrey Serial Correlation Test		0.288	
Heteroskedasticity Test		0.768	
Jarque-Bera Normality Test		0.519	

The linear ARDL bound test results in Table 4 show that F-value = 4.406 is less than I (1) bound = 4.85, which means that we do not reject the null hypothesis and this implies that there is no cointegration between oil price shocks and the selected macroeconomic indicator used in this study. This suggests that we can only specify a short run relationship between oil price shocks and macroeconomic indicators (GDP and Inflation). The Breusch-Godfrey test ($P>0.05$) shows that there is no serial correlation and this indicates that the fitted linear ARDL (1, 0, 0) model does not suffer from the problem of serial correlation. Moreover, the results show that there is no presence of heteroscedasticity (Breusch-Pagan-Godfrey $P>0.05$) and this indicates that the fitted linear ARDL (1, 0, 0) model does not suffer from the problem of heteroscedasticity. Furthermore, the Jerque-Bera test for residual normality shows that the residual is normally distributed at a 5% level of significance.

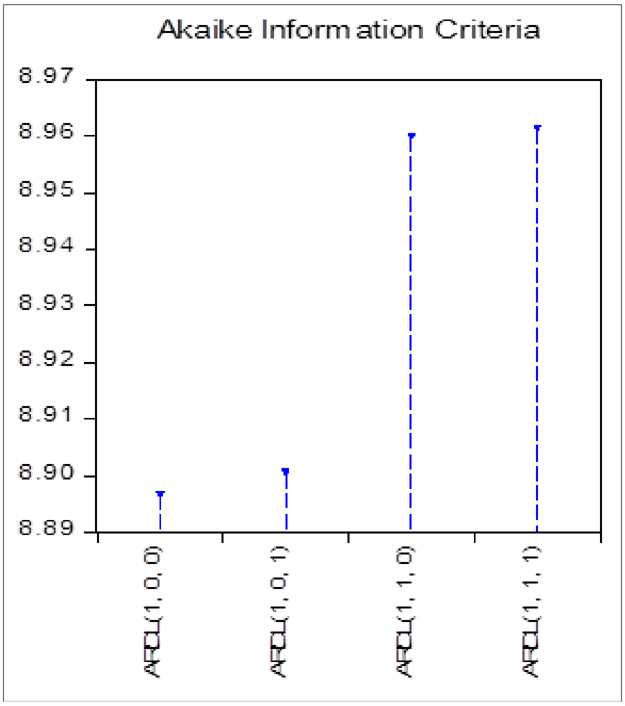

Fig 1: ARDL Cusum Graph

The graph shows that linear ARDL (1, 0, 0) is the best-fitted model among other tentative models because it shows the least Akaike information criteria (AIC) as we can see from the visualization.

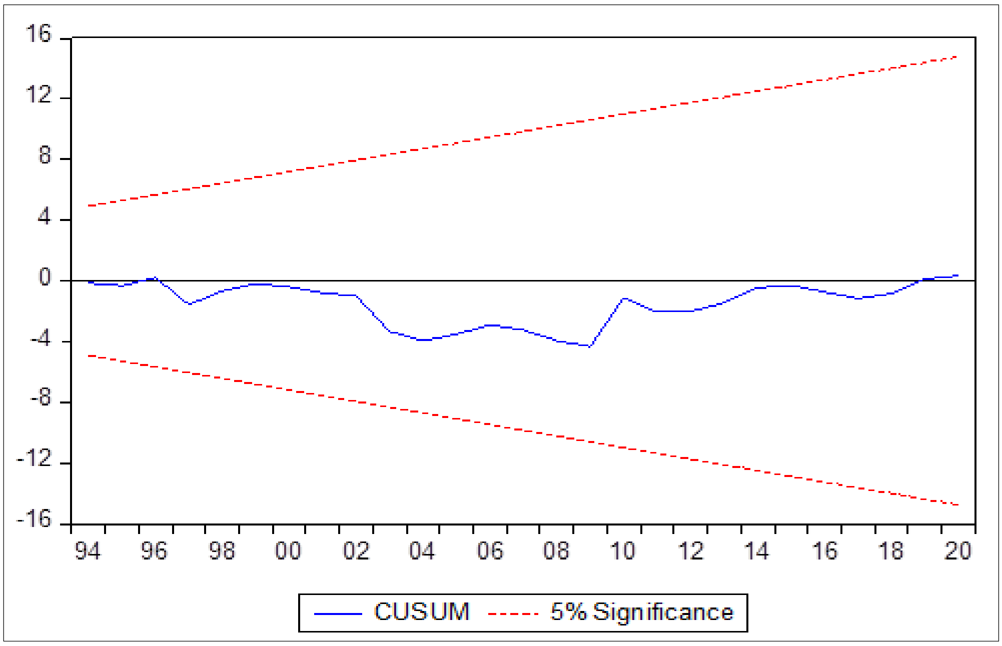

Fig 2: Shows the CUSUM stability test results for the fitted linear ARDL model. It can be seen that the blue lines falls between the two 5% limits and this indicates that the linear ARDL (1. 0, 0) model is stable.

Table 5: NARDL (Non-Linear ARDL)

Dependent Variable: Oil_Price				
Selected Model: ARDL (1, 0, 0, 0, 1)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
OIL_PRICE(-1)	0.220044	0.217211	1.013045	0.3216
GDP_POS	-1.24041	0.72621	-1.70807	0.1011
GDP_NEG	-6.60862	6.328652	-1.04424	0.3072
INFLATION_POS	0.383096	1.010403	0.379151	0.7081
INFLATION_NEG	-2.87477	1.493072	-1.9254	0.0666
INFLATION_NEG (-1)	1.842635	1.248282	1.476136	0.1535
C	2.624704	22.62711	0.115998	0.9087
F-statistic	2.24947	Durbin-Watson stat		1.984748
Prob(F-statistic)	0.074543			

Table 5 results show that the fitted NARDL (1, 0, 0, 0, 1) is statistically significant at a 10% significant level, which indicates that there is an asymmetric relationship between oil price shock and macroeconomic variables. Meanwhile, the negative change in Tanzania's inflation rate ($P<0.10$, $\beta = -2.875$) has a negative significant effect on the oil price shock. This agrees with the current situation in reality as a higher inflation rate suggests an increase in oil prices as commodities and services depend on crude oil for operation.

Table 6: NARDL (1, 0, 0, 0, 1) Model Bound Test

AIC Criteria Model	(1, 0, 0,0,1)		
F statistic	2.717		
Critical Value			
Significance	1%	5%	10%
Critical Value I(0)	3.74	2.86	2.45
Critical Value I(I)	5.06	4.01	3.52
Diagnostic Test			
Breusch-Godfrey Serial Correlation Test		0.522	
Heteroskedasticity Test		0.539	
Jarque-Bera Normality Test		1.118	

Table 6 shows NARDL bound test that F-value = 2.717 is less than I(1) bound = 4.01, which means that we do not reject the null hypothesis and this implies that there is no cointegration between oil price shocks and the selected macroeconomic indicator used in this study. This suggests that we can only specify a short-run relationship between oil price shocks and macroeconomic indicators (GDP and Inflation). The Breusch-Godfrey test ($P>0.05$) shows that there is no serial correlation and this indicates that the fitted NARDL (1, 0, 0, 0, 1) model does not suffer from the problem of serial correlation. The Breusch-Pagan-Godfrey ($P>0.05$) shows that there is no presence of heteroscedasticity and this indicates that the fitted NARDL (1, 0, 0, 0, 1) model does not suffer from the problem of heteroscedasticity. The normality test for the residual of the fitted NARDL ($P>0.05$) using the Jerque-Bera test shows that the residual is normally distributed.

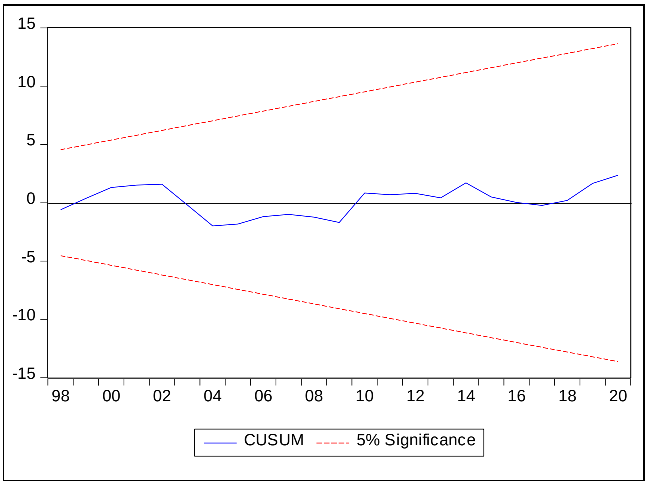

Fig 3: NARDL CUSUM graph

Figure 2 shows a stability test for the fitted linear ARDL model. It can be seen that the blue line falls between the two 5% limits and this indicates that the NARDL (1, 0, 0, 0, 1) model is stable.

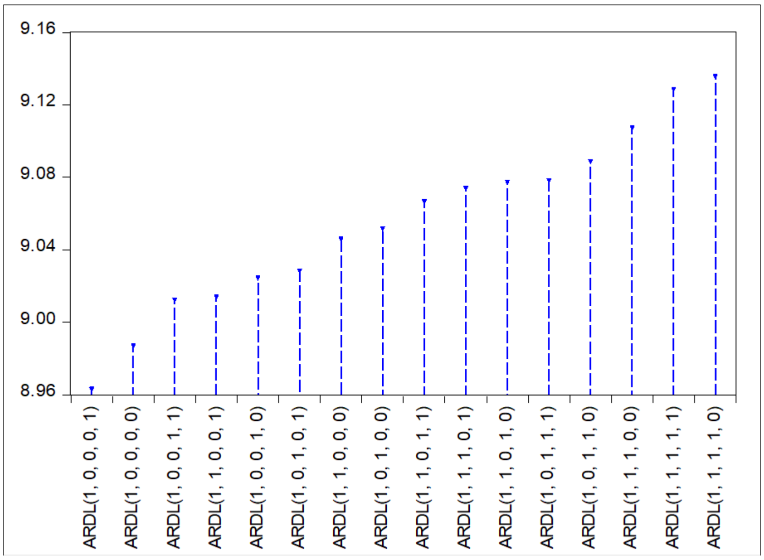

Fig 4: Akaike information criteria

The graph shows that nonlinear NARDL (1, 0, 0, 0, 1) is the best-fitted model among other tentative models because it shows the least Akaike information criteria (AIC) as we can see from the visualization.

Conclusion and Policy Implications

Tanzania tends to grow economically into high middle-income status as a major producer of natural gas and has been exporting the product for more than 50 years but is still an importer of crude oil. This study examines the asymmetric relationship between oil price shocks and macroeconomic fluctuations in Tanzania. The results show that ARDL and NARDL model is statistically significant, which indicates that there is an asymmetric relationship between oil price shocks and macroeconomic variables. The bound test for both the linear model and asymmetric model shows that there is no cointegration, which indicates the specification of short-run association between oil price shocks and macroeconomic fluctuations. However, ARDL shows that the lag 1 of oil price has a positive significant effect while the asymmetric model (NARDL) shows that negative change in the inflation rate of Tanzania has a negative significant effect on oil price shock. The findings of this study are in line with Castillo *et al.* (2010) [6] and Hooker (2002) [16].

Tanzania is, nonetheless, a developing net oil importer economy with a high reliance on energy, specifically crude oil imports for the majority of industrial and socioeconomic activity. Following that, it appears that verifying the relationship between oil price shocks and macroeconomic indicators is critical for effective policy formulation and investment decisions. If there is no consistency in the economy, such as inflation consistency, uncertainty can arise in the economy by lowering the motivation of the policies being implemented. As a result, it is suggested that Tanzania implement policies to reduce macroeconomic volatility. Dynamic consumption may be another alternative for a growing economy that relies on imported oil and is prone to price fluctuations. The macroeconomic variables considered for this study are GDP and inflation based on the data availability and this forms a constraint for other variables which should have been included. Therefore, future studies should be conducted by considering other macroeconomic factors in Tanzania. Moreover, more studies can be conducted in Tanzania using appropriate periods and other methodologies.

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