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Article

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Asymmetric Effect of Oil Price Change on Inflation: Evidence from Sub Saharan Africa Countries

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ABSTRACT

This study is aimed at investigating the asymmetric effect of oil price change on inflation for Sub Saharan Africa (SSA) countries. Based on the findings from the dynamic heterogenous nonlinear panel ARDL estimation, a panel data representation of Shin et al. (2014), the long run asymmetric relationship exists between both oil price increase (op^{+}) and decrease (op^{-}) and inflation for these countries. Nevertheless, the oil price increase tends to exert more effect on inflation than the oil price decrease. Oil serves as a key input to the production process, therefore, changes in its price would have a great influence on the level of inflation which at last may hamper the process of economic progress. For policy implication, the monetary authorities shall pay more attention to the increase in oil price than the oil price decrease in designing appropriate policies of price stability as the former exerts greater impact on inflation than the latter. The price stability as one of the key macroeconomic goals could be attained if these countries understand the oil price-inflation relationship and then monetary measures can be adjusted to endure the effect of oil price changes especially increase in oil price on the price level so that stability in the prices of output can be maintained.

Keywords: Panel Data, PMG, ARDL, Oil Price, Inflation, Asymmetry, Sub Saharan Africa
JEL Classifications: C33, E31, E3

1. INTRODUCTION

Over the past decades most research has comprehensively emphasized on the relationship between oil price and inflation. Basically, the price of oil can have a significant impact on inflation as oil is serve as a key production input to firms for manufacturing of various goods and services. Particularly, higher prices of oil can manifest into exorbitant consumer prices via high cost of production, in which are interpreted as level of inflation (Lacheheb and Sirag, 2019). Therefore, frequent fluctuations in oil prices can also lead to fluctuations in consumer prices and or inflation, which may exert hindrance towards achieving the set target of macroeconomic policy. Thus, maintenance of inflation and price stability within a specified reasonable set target are important macroeconomic policy objectives every economy wishes to have as it reflects a stable and healthy economy. Price stability can positively affect economic growth and development while price instability can create ambiguity by making the economic agents unable to make right and fully informed consumption and investment decision thereby leading to inefficient allocation of resources. Price instability also raises the cost of doing business by raising inflation risk premia (compensation to investor for the loss of value in the investment) in interest rates thereby leading to fall in investments and output (Nusair, 2019).

This development shows that dealing with the issue of oil price-inflation relationship is vital as it tells how the changes in oil price affect the inflation in the domestic economy. For instance, the rise in inflation in the 1970s was associated with the increase in oil price at that particular period. Likewise, the fall in inflation in the past years (1980s and 1990s) were also linked to the fall in the price of oil (Leblanc and Chinn, 2004). Oil price increase exerts delinquent issues to the central banks. A spike in the price of oil leads to the increase in the firms' costs and prices of their products. Ceteris paribus, this triggers an increase in the price level and inflation. Therefore, it is important to empirically understand the connection between oil price changes and inflation so that the firms can adjust their pricing guidelines to go in-line with the prevailing inflationary condition, likewise the policy makers can also adjust the macroeconomic policies to go in line with that (Leblanc and Chinn, 2004). Many empirical studies in the past established that, oil price is positively affecting inflation. For instance, Choi et al. (2018); Nusair (2019); Salisu et al. (2017), and Sek et al. (2015).

In this context, one of the regions that engages with the concern of oil price-inflation relationship is the Sub Saharan Africa (SSA) countries[1]. Essentially, what these SSA countries have in common is that they all import oil for their domestic use. Even though there are some SSA countries that are net oil exporters, yet they import most of the fuel they use. The problem of limited refining capacity is what prompted the oil exporting countries to follow the same suite of fuel-importation with the remaining non-oil exporting countries apart from their oil exportation. Despite the existence of many refineries in various SSA countries still their capacities are very much underutilized and consequently, the vast of the continent's oil resources are being transported overseas to have value added and then returned to the countries as refined petroleum products (Rettig et al., 2013). The lack of investment, decayed infrastructures and poor performing capacity are the factors that made it necessary for countries across Africa to rely on oil importation to meet up with the growing need of fuel demand. The region fuel demand is expected to raise by about 16.3% from approximately 4.3 million barrel per day (mbd) in 2017 to about 5 mbd by 2023 (EIA, 2019). SSA refining capacity is expected to remain low until the investment in the sector become fruitful to yield so much profit to attract investors. And unfortunately, that might be a difficult task as most of the governments of these countries prefer giving subsidy on oil products and they only pay attention to projects that provide leadership with political capital (Oirere, 2018).

These countries are using the imported refined petroleum products for various manufacturing activities as one of the production inputs alongside capital and labor. As such, changes in the oil price are affecting their firms' cost of production and the price level (Lacheheb and Sirag, 2019). The total refined oil consumption by the SSA countries stands to be 51,150.43 million metric tons (mmt) as at 1990 and raised to the tune of 109,107.7 (mmt) by 2016 (EIA, 2019), a growth of 113% within the period of 27 years. Figure 1 shows the trend by which the oil consumption persists for SSA countries between the period (1990 to 2016) 27 years.

As such, movement in oil price in the global market is affecting the domestic price level in these SSA countries for the reason that most of the economic activities rely on oil resource as source of energy. Figure 2 below, shows the plot of oil price (WTI) and CPI for the SSA countries. This indicates that the correlation of the two variables are moderately high with a correlation coefficient of 0.67, indicating that the two variables are in tandem with about 67 percent relationship.

It is also worth mentioning here that fluctuations in oil price affect the economies of many countries as oil resources serve as major production inputs to various manufacturing activities[2]. As stated by Lacheheb and Sirag (2019), changes in oil price affect production cost and in turn production cost may put upward pressure on the price level. If oil price rises up, the cost of production increased, and the price level raises up too. In contrast, if the oil price falls, the cost of production reduced too but not exactly the same way as oil price increase triggers increase in the price level (inflation). This is largely due to the downward price rigidity as highlighted by Lacheheb and Sirag (2019) and Nusair (2019). This unequal effect of oil price changes to inflation is what is referred to as asymmetric effect, in which has been largely ignored in previous studies, explicitly for the case of SSA countries. However, only limited studies that have stressed on an asymmetric relationship between oil price and inflation. For example. Nusair (2019) discovered that there is an asymmetric relationship between oil price and inflation, with significant oil price increase and insignificant oil price decrease on inflation. While Salisu, Isah, Oyewole and Akanni (2017) found that an asymmetric effect of oil price change on inflation, with oil price increase exerting more effect than the oil price decrease.

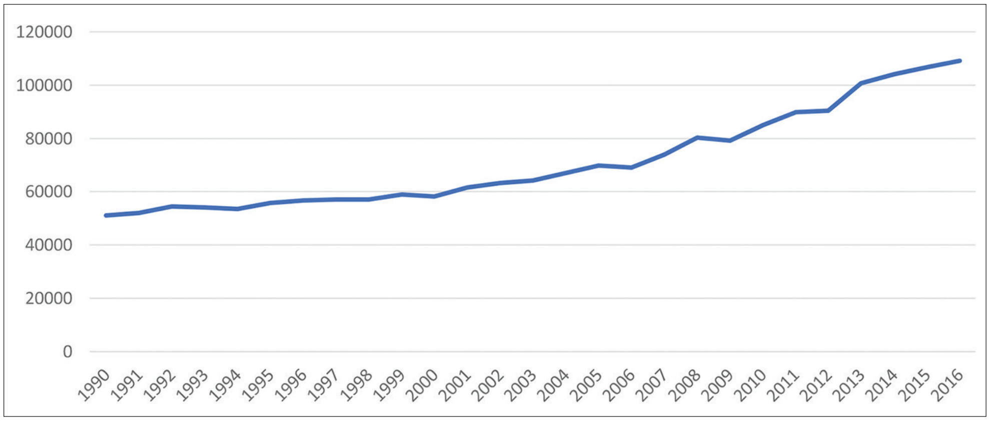
Against this background, this study puts a step ahead in order to better understand the nature of oil price-inflation relationship in a more extensive manner. In view of that, this study exclusively aimed at investigating the asymmetric effect of oil price change on inflation for SSA countries that covers the period (1990 to 2018). Specifically, this study inspects the short-run and long-run effects of oil price shocks on inflation, which allows for asymmetric oil price shocks. The empirical method employed is based on the nonlinear panel ARDL (or PMG) method in which the asymmetric relationship between oil price and inflation can be appropriately examined by introducing a positive and negative partial sum decompositions of oil price through the short-run and long-run nonlinearities relationships.

This study provides exceptional contributions to the literature on oil price-inflation. To the best of authors' knowledge, this is the first study that apply a nonlinear panel ARDL (PMG) method to explore the asymmetric effect of oil price change on inflation for the SSA countries where such kind of study is scanty. The study is also imperative as these countries (SSA countries) would understand the oil price-inflation asymmetric relationship so that emphasis should be placed more on the particular change in oil price (either positive or negative) that affect inflation most so that macroeconomic policy can specifically be designed in such a way of tackling that. Using of panel data has advantages in giving out identification that can never be identified by either using pure time-series or pure cross-sectional data (Law, 2018). The benefits of using panel data are as

1 Sub Saharan Africa is a sub-region on African continent that geographically lies on the southern part of Sahara. It consists of 48 countries which covers all African countries except the northern part of the continent as presented in Appendix I. These countries share the same race but different tribes, they speak different languages (both native and official), some are Anglophones while some are Francophones. Religious wise, different faiths are found across the nations. Economically, these countries fall within the category of middle- and lower-income countries as illustrated in Appendix II.

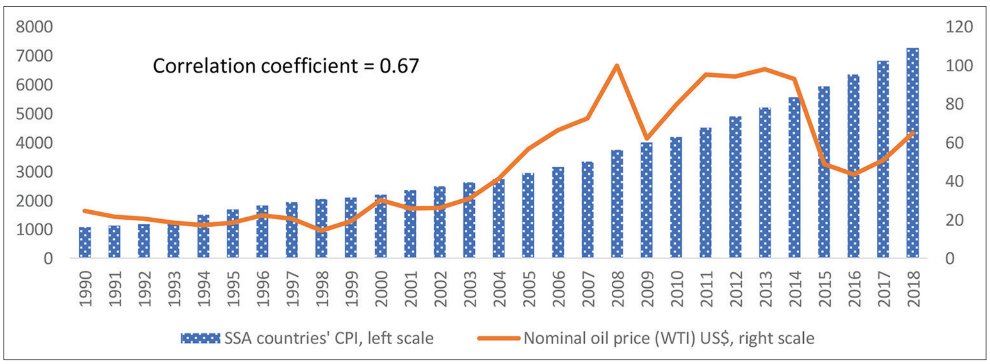
2 Please refer to Kriskkumar and Naseem (2019) for detail discussion.

Figure 1: Refined petroleum products consumption (mmt).



Source: Estimated from the data obtained from EIA. The data is for SSA Countries (1990 – 2016)

Figure 2: Consumer Price Index (CPI) and Nominal oil price



Source: Author's illustration based on the data obtained from WDI and EIA. The data is for 42 SSA Countries (1990 – 2018)

follows: Firstly, in controlling for individual heterogeneity. These heterogenous nature are different unobserved features of individual groups or units that can lead to a biased estimate. Secondly, panel data can be easily used to study the dynamics speed of adjustment than mere cross-sectional or time-series data. Cross-sectional data can portray nothing about dynamism while a time-series can take a lengthy time before giving out a dynamic outcome but using this same cross-sectional data together with the time series can give a better dynamic picture of the data easily. Finally, panel data gives more information data sets than cross-sectional or time series data due to the pooling of individual units and time dimensions altogether and come out with a larger sample size with less collinearity.

The remaining parts of the paper are organized as: section 2 reviews strand of literature on oil price-inflation. Section 3 explains the empirical model, methodology and data; section 4 reports the estimated results of panel unit root test, panel estimations and the interpretations of the findings while the last section, section 5 concludes the discussion

2. LITERATURE REVIEW ON THE EFFECT OF OIL PRICE CHANGE ON THE LEVEL OF INFLATION

Fluctuations in the price of oil affect the economic activities of countries for various purposes as oil is considered to be one of the production inputs alongside capital and labor (Nusair, 2019). The effect of oil price on price level may take place through supply channel (Kilian, 2014). The effect of oil price change through the supply channel is leading to increase in the price level and decrease in output. Firms might be facing the dilemma of either increasing the price of goods or cut production whenever the price of oil increased, sometimes they are even facing the risk of both increasing the price and reducing production when the raising oil price is too high. Similarly, when the oil price falls, the costs of production decrease too, the price of outputs is expected to fall if there is absence of downward price rigidity. In the case where nominal wage rigidity is present, this may not happen. The price might not be reduced and even if it is going to be reduced it will be decreased by a little amount when compared to the increase in oil price and that is asymmetry. The oil price change is important enough to affect the economic activities of various countries, as emphasized by (Kilian, 2014), the cost push inflations that the United States had experienced in the 1970's were the consequences of oil price shocks affected macroeconomic variables including inflation. Sadorsky (2006) considered oil as blood of a modern economy and believes that if the increase in oil demand does exist and no development in their supply, it will increase oil prices. The forces of supply and demand in oil prices are significant in determining oil prices. Barsky and Kilian (2004) employed Gordon (1984) type model to show that oil price shocks can be inflationary by reducing industrial production which could generate stagflation. Further, oil price shock could have a long-term implication for economic growth.

Obviously, majority of the past studies on oil price nexus assumed that relationship between oil price and many economic activities is linear, however, this may not necessarily hold because that notion had already lost popularity since 1980s as most of the macroeconomic variables proved the features of nonlinearity. Hamilton (1983) demonstrated a strong correlation between oil price changes and gross national product (GNP) growth in U.S. data. However, his study pertained to a period in which all the large oil price movements were upward, and thus the question whether the correlation persists in periods of price decline was left unanswered. Moreover, the price variable he used was somewhat distorted by price controls in the 1970s. Mork (1989) was the among the first to consider the asymmetric effect of oil price on output. He investigates whether Hamilton's results continue to hold when the sample was extended to include the then recent oil market collapse and the oil price variable was corrected for the effects of price controls. Particular attention was given to the possibility of asymmetric responses to oil price increase and decrease ($ROILP_t^+/ROILP_t^-$). Thus, Mork (1989) proposes an asymmetric definition of oil price and distinguishes between positive and negative oil price changes. He allowed for asymmetries in the price of oil and derived positive and negative oil price shocks.

Empirically there is large body of researches in the literature investigating the oil price relationship with other macroeconomic variables including inflation. Study on oil price-inflation relationship is vital as it tells how the changes in oil price affect the inflation in the domestic economy and understanding that is important as it helps the authorities in designing the appropriate policies to control inflation in the country. Economic activities rely on oil, hence, increase in oil price is raising the cost input of production thereby causing the price level to rise. As such, that highlight for the need of an in-depth analysis of oil price-inflation nexus. Choi et al. (2018) investigate the impact of global increase of oil price on domestic inflation on panel of 72 developed and developing countries over the period (1970-2015) by using Impulse Response Function (IRF) by local projections. The findings show that global oil price changes are positively affecting domestic inflation. Sek et al. (2015) investigate the impact of oil price changes on inflation for the two sets of countries they categorized as low-oil-dependents (industrialized) and high-oil-dependents (oil exporting) nations by applying a pooled mean group (PMG) method on annual data for the period (1980-2010). The findings indicate that oil price has a positive and significant effect on inflation on low-oil-dependency countries (oil exporters).

Similarly, Salisu et al. (2017) examined the oil price inflation nexus for the panel of selected oil exporting and importing countries using a nonlinear panel ARDL method on quarterly data over the period (2000-2014). The variables CPI was used as a measure of inflation, London-brent as a measure of oil price and industrial production index as a measure of GDP. The results indicate that both increase and decrease in oil prices are positive and significant, meaning that oil price increase is inflationary while oil price decrease is deflationary. Nusair (2019) investigates the non-linear effect of real oil price changes on inflation on Gulf Corporation Council (GCC) countries using ARDL, NARDL and PMG for the period (1970-2016). The finding indicates that increase in real oil price is positively affecting inflation in the investigated area while the negative oil price is either insignificant or is having a lesser effect on inflation. It is also indicated that there is long run and significant relation between the variables (inflation and real oil price). Also, Lacheheb and Sirag (2019) examined the oil price change-inflation relationship on Algeria (1970-2014) using non-linear autoregressive distributed lag (NARDL) method. The findings indicate that, increase in oil price has a positive and significant effect on inflation rate in the investigated area, whereas a decrease in oil price effect on inflation was found to be insignificant. The reason behind that is, even though Algeria is expected to have more revenue as oil price increases which may raise the level of GDP, but at the same time many productions of goods and services require oil as an input to the production process. Therefore, production relates to the prices of refined oil and oil in general which may translate into increase in the price level. Also, many of the commodities that are used locally within the country are products of other nations which affected by the increase in oil price thereby importing them with the inflation into the country. Again, to investigate the impact of oil price on the prices of gasoline and natural gas, Atil et al. (2014) employed a non-linear ARDL method on monthly data over the period (January 1997 to September 2012). WTI was used to measure oil price, gasoline to measure petrol and Henry Hub natural gas to measure natural gas. The findings indicate that oil price affect gasoline and natural gas prices positively but in a non-linear manner.

In contrast, Davari and Kamalian (2018) conducted a study on Iran to investigate the asymmetric oil price-inflation relationship by employing a nonlinear ARDL method to determine the positive effect as well as the negative effect of oil price on inflation utilizing quarterly data covering the period of 12 years (2003-2015). Consumer price index (CPI) was used as a proxy to inflation while oil price was used as a proxy to oil revenue. The findings indicate that there is significant relationship between oil price decrease and inflation while the oil price increase on inflation was appeared to be insignificant. There is also evidence which is showing oil price impact on inflation is more vigorous on the countries that are setting inflation target or simply inflation targeting countries than their counterparts (non-inflation targeting countries). Inflation targeting means, a monetary policy which a central bank of a particular country explicitly set and follow inflation target for medium term and announce it to the public. For instance, to assess the oil price pass through impact on consumer prices for inflation-targeting and non-inflation-targeting countries, López-Villavicencio and Pourroy (2019) employed a GMM and state-space model utilizing both quarterly and annual data on 49 countries (advanced and growing economies) out of which 26 are inflation targeting while 23 are non-inflation targeting countries. The results indicate that the oil price pass through effect is larger for inflation targeting than non-inflation targeting countries.

However, despite the plethora of studies showing oil price is very well affecting inflation, there is also evidence that in some instance the impact of the latter on the former is in moderation not as previously determined by other studies. For instance, Leblanc and Chinn (2004) employing the augmented Phillips curve framework to study the impact of oil price changes on inflation for 5 countries

(United States, United Kingdom, France, Germany and Japan) using a quarterly data between the period 1980 Q1 to 2001 Q4. The results show that, oil price increase causes a modest effect on inflation for the United States, Japan and Europe.

Another strand of literature has discovered that the relationship between oil price increase and inflation is not even of significant importance. Proponent about these are studies such as Basnet and Upadhyaya (2015) that examine the effect of oil price shocks on macroeconomic variables (including inflation) for ASEAN-five countries employing a structural VAR (SVAR) method over the period (1970Q1-2010Q2). The findings indicate that increase in oil price shock has no any significant long run impact on inflation and other macroeconomic variables incorporated in the study. This is due to the fact that most of the effects of oil price shocks are blended shortly into the economy as they are absorbed within five to six quarters. Similarly, Çatik and Önder (2014) employing a Markov regime-switching approach to investigate the oil price pass through impact on inflation in Turkey utilizing a monthly data for the period between 1997 February to 2007 May. Harmonized index of consumer price (HICP) was used as a proxy of inflation, west texas intermediate (WTI) as proxy of inflation and output gap was derived via using Hodrick-Prescot formula as a difference between the actual and potential output. The findings indicate that oil price changes do not affect inflation in either of the inflationary regime (higher or lower inflationary periods). Oil price affects inflation, hence oil price itself is being affected by either change in aggregate demand or change in aggregate supply. However, there is increasing evidence that changes in aggregate demand is found to be more powerful in influencing the oil price than its counterpart aggregate supply change. For instance, Valcarcel and Wohar (2013) employed a Bayesian Structural Vector Autoregressive (BSVAR) method to study the various aggregate shocks on real oil price and its pass-through effect to consumer prices. They utilized a quarterly on United States data for the period 1948 Q1 to 2011 Q2. The findings indicate that aggregate demand shocks have more impact on oil price than the aggregate supply shocks and the oil price volatility does not seem to be affecting the changes in inflation.

Overall, from the strand of literature reviewed, it has shown that the long run relationship between oil price and inflation is in diverse ways. Several studies came out with different findings, some find oil price to be positively affecting inflation, some find oil price to be negatively affecting inflation, others find oil price to be moderately impacting inflation while others even find no significant relation between oil price and inflation. This is indicating there is absence of a clear consensus in the empirical literature of oil price-inflation relationship. Again, there is scanty of studies in the literature regarding to Sub Saharan Africa (SSA) on oil price-inflation relationship as most of the previous studies were conducted on advanced oil importing and other emerging economies of the world overlooking SSA countries despite the important role that oil plays to their economies. Equally important, one of the limitations of a previous study by Nusair (2019) is that, it is a bivariate model considering only oil price and inflation, as such, the author suggested the use of multivariate model by incorporating other relevant variables in the model to see their impact on oil inflation. There upon, for the purpose of this study, a multivariate model is formed with additional explanatory variables in addition to oil price to test their relevant impact on inflation.

3. EMPIRICAL MODEL, METHODOLOGY AND DATA

3.1. Model Specification

The empirical specification is aimed at investigating the asymmetric relationship between real oil price and inflation on panel data for SSA countries. Thus, the study follows the works of Sek et al. (2015); Salisu et al. (2017); Davari and Kamalian (2018); Lacheheb and Sirag (2019) and Nusair (2019):

$$lcpi_{it} = \alpha_{it} + \beta_1 lop_{it} + \beta_2 lrgdpc_{it} + \beta_4 lreer_{it} + \beta_4 gap_{it} + \eta_i + \varepsilon_{it} \quad (1)$$

where *lcpi* is the natural log of consumer price index, *lop* is the natural log of real real oil price[3], *lrgdpc* is the natural log of real GDP per capita (constant 2010 US$), *lreer* is the natural log of real effective exchange rate and *gap* is the output gap[4]. The output gap is used to capture the fluctuation effects of real GDP on inflation, and η_i is the unobserved country specific effect and ε is the independent and identically distributed error term, *i* is the country index while *t* is the time index.

Based on the theory, the coefficient *lop* is expected to be positive $(\beta_1>0)$, signifying as real oil price increases, inflation increase also in oil exporting countries. This is showing the positive effect of the increase in real oil price to the price level. Meaning that increase in real oil price is creating a rise in demand to cost of production, there by triggering a rise in the price level, which is inflationary (Sek et al., 2015; Salisu et al., 2017; Lacheheb and Sirag, 2019 and Nusair 2019). Next, the coefficients *lrgdpc* is expected to be positively signed $(\beta_2>0)$ as increase in GDP is increasing the rate of inflation. This is since, countries make higher income (or output) may lead to the increase in their aggregate demand, and increase in consumption and price levels, which is also known as inflation rate (Sek et al., 2015 and Salisu et al., 2017). For the exchange rate, the coefficients lreer is expected to be negative $(\beta_3>0)$ as appreciation in real effective exchange rate tends to lower inflation in the long run. The appreciation in the local domestic currency makes domestic goods expensive in the international market, which then lowers demand and production thereby causing drop in the price level. Sek et al. (2015) found that exchange rate appreciation is negatively affecting inflation for oil exporting countries. Then, the coefficient of output gap is expected to have a positive sign $(\beta_4>0)$, signifying that inflation increases when the aggregate output is greater than potential capacity as indicated by Lacheheb

3 In order to control the effect of nominal exchange rate variations on oil price, the WTI was transformed to real oil price by converting it to each countries' nominal exchange rate and then scale it to the respective consumer price index (CPI) of each country under the study

4 It is computed as the difference between the log of real GDP and the *Hodrick-Prescott* filtered trend of the log of real GDP

and Sirag (2019) and Nusair (2019) who found that output gap is positively affecting inflation.

To account for asymmetries in the model, the approach by Shin, Yu and Greenwood-nimmo (2014) is followed. In the approach, the decomposition of real oil price into partial sum decompositions of changes is simplified. In a linear symmetric model, the positive and negative impact of oil price on inflation are assumed to be identical whereas in the case of asymmetric model, the positive and negative effects on inflation are assumed to be different. The asymmetric model is trying to test whether the oil price increase have greater effect on inflation than the oil price decrease. Therefore equation 2 become with replacement of real oil price with the decomposition of real oil price into partial sum decompositions of positive and negative changes in real oil price.

$$lcpi_{it} = \alpha_{it} + \beta_1 lop^{+} + \beta_2 lop^{-}{}_{it} + \beta_2 lrgdpc_{it} + \beta_4 lreer_{it} + \beta_4 outputgap_{it} + \eta_i + \varepsilon_{it} \quad (2)$$

where lop^{+} *and* lop^{-} are decomposed oil price into partial sum of decomposition of positive and negative changes.

3.2. Econometric Methodology

In this study, nonlinear ARDL as proposed by Shin et al. (2014) in a panel data form is the econometric method employed. It is in the form of nonlinear representation of a dynamic heterogenous panel (ARDL) estimators of Mean Group (Pesaran and Smith, 1995), Pooled Mean Group (Pesaran et al., 1999) as used by Nusair (2019); Salisu and Isah (2017), and Salisu et al. (2017) Abdlaziz et al., (2018 and 2020). The Pooled Mean Group (PMG) allows short-run coefficients, speed of adjustment and error variances to vary across panels and at the same time restrict the long-run coefficients to be similar across the groups. The PMG also generates consistent estimates of the mean of the short run coefficients by taking the simple average of individual unit coefficients. The Mean Group (MG) method of estimation assumed that both slopes and intercepts can differ across panels/countries that is why the long-run coefficients are not similar across panels. The Hausman (1978) test is conducted after the estimation of PMG and MG to get the appropriate method between the two. The null cannot be rejected if the long run homogeneity exists, and therefore PMG is more efficient. The choice of nonlinear panel ARDL for this study was motivated due to the fact that it allows the combination of I(0) and I(1) variables, it allows the estimation of nonlinear asymmetric relationship by decomposing the variable of interest into partial sums of decomposition of positive and negative changes and it captures heterogeneity effects across panels. And also, a Wald test is carried out after the MG, PMG estimations in order to find whether the model is asymmetric. The null will be rejected if the long run or short run asymmetry exists.

Starting with the linear symmetric model, the dynamic heterogeneous panel regression can be incorporated into the error-correction model using the ARDL (p, q) method, where p is the lag of the dependent variable, and q is the lag of the independent variables, the Akaike information criterion (AIC) is used for the selection of the lag order:

$$\begin{aligned} lcpi_{it} &= \gamma_i lcpi_{i,t-1} + \delta_1 lop_{it} + \delta_2 lrgdpc_{it} + \delta_3 lreer_{it} + \delta_4 gap_{it} \\ &+ \sum_{j=1}^{p-1} Y_{ij} \Delta lcpi_{i,t-j} + \sum_{j=1}^{p-1} \beta_{ij} \Delta lop_{i,t-j} + \beta_{ij} \Delta lrgdpc_{i,t-j} \\ &+ \beta_{ij} \Delta lreer_{i,t-j} + \beta_{ij} \Delta gap_{i,t-1} + \eta_i + \varepsilon_{it} \end{aligned} \quad (3)$$

From equation the equation (3) above, the following equation (4) is be formed, which is specifying the nonlinear asymmetric model with decomposed oil price into partial sum of decomposition of positive and negative changes (oil^{+} and oil^{-}) as established by Shin, Yu and Greenwood-nimmo (2014).

$$\begin{aligned} lcpi_{it} &= \gamma_i lcpi_{i,t-1} + \delta_1 lop_{it}^{+} + \delta_2 lop_{it}^{-} + \delta_3 lrgdpc_{it} + \delta_4 lreer_{it} \\ &+ \delta_5 gap_{it} + \sum_{j=1}^{p-1} Y_{ij} \Delta lcpi_{i,t-j} + \sum_{j=1}^{p-1} (\beta_{ij}^{+} \Delta lop_{i,t-j}^{+} \\ &+ \beta_{ij}^{-} \Delta lop_{i,t-j}^{-}) + \beta_{ij} \Delta lrgdpc_{i,t-j} + \beta_{ij} \Delta lreer_{i,t-j} \\ &+ \beta_{ij} \Delta gap_{i,t-1} + \eta_i + \varepsilon_{it} \end{aligned} \quad (4)$$

where δ is the long-run coefficient of the independent variables, and γ is the parameter of speed adjustment to the long-run equilibrium. η is the fixed effect and ε_{it} is the error term. i and t represents country and time index respectively. It is assumed that the error term ε_{it} in the PMG framework is distributed independently across i and t with zero mean and variance. The error term is also distributed independently of the regressors. Moreover, to capture the long-run relationship between dependent and independent variables, it is assumed that if the parameter of the speed of adjustment is <0 ($\gamma < 0$) for all i, then panel co-integration is expressed as:

$$lcpi_{it} = \varphi_1 lop_{it} + \varphi_2 lrgdpc_{it} + \varphi_3 lreer_{it} + \varphi_4 gap_{it} + \mu_{it} \quad (5)$$

$$lcpi_{it} = \varphi_1^{+} lop_{it}^{+} + \varphi_2^{-} lop_{it}^{-} + \varphi_3 lrgdpc_{it} + \varphi_4 lreer_{it} + \varphi_5 gap_{it} + \mu_{it} \quad (6)$$

Where $-\varphi_1 = \delta_1 / \gamma_i, -\varphi_2 = \delta_2 / \gamma_i, -\varphi_3 = \delta_3 / \gamma_i, -\varphi_4 = \delta_4 / \gamma_i \; and \; -\varphi_5 = \delta_5 / \gamma_i$ are the long run coefficients of oil price positive, oil price negative, real GDP per capita, real effective exchange rate and output gap respectively.

3.3. Data and Descriptive Statistic

In this study, annual data is used to estimate the long run asymmetric relationship between oil price change and inflation for for 42 Sub-saharan Africa (SSA) countries (Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Congo (The Republic), Cote d'Ivoire, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Pricipe′, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda and Zambia), covering the period of 29 years (1990-2018) subject to availability of data. The study, therefore, as indicated on Table 1 used inflation proxied by consumer price index - CPI (2010=100) as a dependent variable while the explanatory variables are oil price (WTI) US$, real GDP per capita (constant 2010 US$), real effective exchange rate (constant 2010 US$) and output gap. In order to control the effect of nominal exchange rate variations on oil price, the WTI was transformed to real oil price by converting it to each countries' nominal exchange rate and then scale it to the respective consumer price index (CPI) of each country under the study. Output gap is computed using Hodrick-Prescott (HP) filter, it is the difference between the log of real GDP and HP filtered trend of the logged real GDP. The data of CPI, real GDP per capita were obtained from the database of world development indicators (WDI). The Real effective exchange rate is obtained from Bruegel. The data of oil prices is obtained from U.S. Energy Information Administration (EIA).

4. EMPIRICAL RESULTS

4.1. Panel Unit Root Test

Being that oil resources serve as the main production input to all the SSA countries regardless of being oil importers or exporters. Therefore, changes in price are reflecting to the changes in the firms' cost of production, price level and inflation. To explore the short and long-term relationship between oil price change and inflation for the panel of these (SSA) countries, a panel unit root test was first conducted to ensure stationarity of the variables. The Levin et al. (2002) LLC which assumes a common unit root process and Im et al. (2003) IPS which assume individual unit root process were carried out and reported in Table 2. The results show a mixture of order integration for the variables, some are stationary at level I(0) while others at first-difference I(1). The test results indicate that under LLC (intercept) at level, variables of CPI (lcpi), oil price (lop) and real effective exchange rate (lreer) are stationary at 1%, but real GDP per capita (lrgdpc) is not significant. Under IPS (intercept) at level, variables lcpi, lreer are stationary at 1% while lop is significant at 5% and lrgdpc is not significant. Under LLC (intercept and trend) variables lcpi, lrgdpc and lreer are stationary at 1% while lop is insignificant. Under IPS (intercept and trend) variables lcpi, lreer are significant at 1%, lrgdpc at 10% but lop is insignificant. And then, all the variables are stationary at first-difference for both trend and intercept under both LLC and IPS tests are significant at 1% level of significance. This make the data qualified in fulfilling the requirement to go ahead with ARDL estimation that allowed the combination of both I(0) and I(1) variables, hence the panel cointegration estimation.

4.2. Symmetric and Asymmetric Results

The PMG, MG results were computed and then results were subjected to Hausman (1978) test for making preference of the appropriate method to take. The rejection of the null is indicating the absence of the long run homogeneity (MG is appropriate) while non-rejection of the null is signifying the presence of long run homogeneity (PMG is appropriate). In this study, the Hausman test result clearly indicates the PMG is the appropriate estimator as the null hypothesis is not rejected as displayed in Table 3. As such, the results from the preferred estimate, PMG are going to be explained.

Taking a glance of Table 3 (model 1 – without asymmetry), the PMG results indicate that inflation responds to the changes in oil price. There is positive and significant relationship between oil price and inflation, denoting that as real oil price increases by 1% the inflation rises by 0.44%. This is consistent with the findings such as Lacheheb and Sirag (2019), Nusair (2019) and Sek et al. (2015). For the remaining control variables, real GDP per capita is significant and negative denoting a 1% increase in real GDP is leading to the decrease in inflation by 0.27%. This might be attributed to the nonchalant attitude of the people toward the manufacturing activities or nonperformance of the manufacturing sector in these countries. the real effective exchange rate is significant and negatively signed as expected similar to tthe finding of Sek et al. (2015), which is showing as real exchange rate increase by 1%, inflation will drop by 1.028%. Output gap is significant but negatively signed which is denoting as aggregate output exceeds the potential capacity, the rate of inflation rises. The convergence coefficient is significant and negative as expected signifying speed of adjustment to the long run equilibrium as 11.7% when any deviation occurs in the short run, and the duration it takes to converge to the long run equilibrium is 8.54 years. In the short run, the results indicate oil price is significant but negatively affecting inflation in the SSA countries while the output gap is positive and significantly affecting inflation.

Moving to the Asymmetric regression result in model 2 of Table 3 (with asymmetry), the long run positive and negative oil prices tend to have a significant and positive effect on inflation. The long run asymmetric results indicate that, an increase in the price of oil is inflationary while a decrease in the price of oil is disinflationary. The asymmetry is indicated by the magnitude of their different coefficient values. Positive oil price change is higher than the negative oil price change, meaning that oil price increase has more effect on inflation than oil price decrease. The results indicate that a pass-through effect of oil price on inflation does not exists as 1% change in oil prices is leading to <1% change in inflation. The Wald test for asymmetry is significant in the long run but insignificant in the short run, validating the existence of long run asymmetric relationship between oil price changes and inflation. For the long run positive oil price change, as oil price increased the inflation raises also, if oil price increased by 1%, inflation rate tends to increase by 0.25% and the result is consistent with findings of Lacheheb and Sirag (2019), Nusair (2019) and Abdlaziz et al (2020). For the negative long run oil price change, inflation decreases as oil price falls, if oil price falls by 1%, inflation rate tend to decrease by 0.19% and this in line with the findings of Davari and Kamalian (2018). This is largely due to the effect of depending on oil as major production input to all the countries (both exporters and importers of oil) and also, it is a major source of revenue to the oil exporters among the SSA countries.

By considering the remaining explanatory variables, for instance, real GDP is positive and significant, indicating a positive effect of real GDP on inflation. Real effective exchange rate is negative and significant indicating an appreciation in real effective exchange rate tends to lower inflation in the long run. The appreciation in the local domestic currency makes domestic goods expensive in the international market, which then lowers demand and production thereby causing drop in the price level. The convergence coefficient

Table 1: Descriptive statistic of annual data for SSA countries (1990-2018)

Variable	Source	Unit of measurement	Mean	SD	Max	Min
lcpi	WDI	2010=100 US$	79.0629	51.1291	440.672	$4.10e^{-10}$
lop	EIA	WTI US$ per barrel	47.4703	28.6271	99.75	14.4
lrgdpc	WDI	Constant 2010 US$	2075.503	3010.103	164.337	20512.9
lreer	Bruegel	Constant 2010 US$	109.4077	31.87955	341.464	32.8831

WDI refers to the World Indicator Development and EIA is the Energy Information Administration

Table 2: Levin-Lin-Chu (LLC) and Im-Pesaran-Shin (IPS) unit root test

Variable	Level				First difference			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	LLC	IPS	LLC	IPS	LLC	IPS	LLC	IPS
lcpi	−6.3817[a]	−2.4559[a]	−9.0698[a]	−3.6726[a]	−11.1188[a]	−11.8218[a]	−10.4956[a]	−11.2387[a]
lop	−4.2679[a]	−1.7880[b]	−0.4781	0.3975	−17.2164[a]	−19.9473[a]	−12.7583[a]	−16.8897[a]
lrgdpc	−0.3991	4.5447	−3.7260[a]	−1.4382[c]	−10.8164[a]	−13.2213[a]	−8.9190[a]	−10.4830[a]
lreer	−5.7682[a]	−5.6530[a]	−8.4209[a]	−6.1924[a]	−17.0025[a]	−18.5256[a]	−13.4175[a]	−15.8773[a]

[a,b] and [c]denote significance level at 1%, 5% and 10% respectively

Table 3: Linear and nonlinear panel ARDL (MG, PMG) results

	Model 1: without Asymmetry Lag order (1,3,1,1,1)		Model 2: with Asymmetry Lag order (1,2,2,2,2,1)	
	Mean group (MG)	Pooled mean group (PMG)	Mean group (MG)	Pooled mean group (PMG)
Long run coefficients				
lop	0.9180[b] (0.3965)	0.4401[a] (0.0197)		
lop^{+}			0.9486[b] (0.3807)	0.2561[a] (0.0308)
lop^{-}			−0.4277 (0.4828)	0.1908[a] (0.0648)
lrgdpc	−4.6699 (4.6022)	−0.2718[a] (0.1006)	−0.4706 (4.1091)	0.5486[a] (0.0681)
lreer	−1.3281[a] (0.5113)	−1.0280[a] (0.0795)	−0.3030 (1.6018)	−1.0256[a] (0.0752)
gap	−4.0829[c] (2.3771)	−0.2340[a] (0.0629)	8.6309 (8.5272)	−0.0157 (0.0498)
Short run coefficients				
Δlop	−0.0381[a] (0.0124)	−0.0286[b] (0.0139)		
Δlop^{+}			0.0144 (0.0504)	0.0116 (0.0395)
Δlop^{-}			0.0249 (0.0369)	0.0202 (0.0333)
$\Delta lrgdpc$	−0.9118[b] (0.4966)	−0.1948 (0.1400)	−0.0495 (0.1707)	0.0411 (0.0735)
$\Delta lreer$	0.0664 (0.0489)	−0.0180 (0.0511)	0.0556 (0.0519)	0.1431[a] (0.0415)
Δgap	1.3025[c] (0.7407)	0.2628[b] (0.1119)	1.2592[c] (0.7277)	0.1167 (0.0935)
Convergence Coefficient	−0.2113[a] (0.0313)	−0.1177[a] (0.0178)	−0.2234[a] (0.0457)	−0.1150[a] (0.0202)
Long-run Wald test				4.5201[b] (0.034)
Short-run Wald test				0.13 (0.715)
Hausman test		2.04 (0.7276)		1.63 (0.8978)
Log likelihood		2007.423		2191.845
No of countries		42		42
No of obs.		1092		1134

Numbers in parentheses are asymptotic standard errors except for Hausman test and Wald tests. AIC criterion is used to choose the lag order. [a,b] and [c]denote significance level at 1%, 5% and 10% respectively

is significant and negative as expected, signifying a speed of adjustment to the long run equilibrium as 11.5 percent when any deviation occurs in the short run, and the duration it takes to converge to the long run equilibrium is 8.69 years.

4.3. Robustness Checks

For robustness checks, Fixed Effect (FE) was used to check the sensitivity of the results to static estimation method. From Table 4 this study presents a Fixed Effect (FE) technique to re-estimate both the linear (symmetry) and non-linear (asymmetry) models and the results are found to be robust to this method. For the linear Fixed effect (FE) model a, the results show that the lag dependent variable is significant indicating the model is dynamic and inflation is persistent. The variable of interest (oil price) is positive and significant signaling that oil price is an important determinant of inflation for SSA countries. for the remaining control variables, real gdp is positive and significant, showing that economic growth is positively affecting inflation. Real effective exchange rate is significant but negative, indicating an appreciation in exchange rate is leading to fall in inflation. For the asymmetric non-linear (FE) model b, positive oil price is found to be insignificant. Negative oil price is positive and significant, indicating that fall in oil price is an important determinant of inflation, this is similar to robustness checks of (Nusair, 2019). The remaining variables, real gdp is positive and significant, signaling that economic growth is positively affecting inflation. The Real effective exchange rate is significant but negative also, indicating an appreciation in exchange rate is leading to a decrease in inflation.

Table 4: Robustness checks

	Fixed effect	
	Model 1: without Asymmetry	Model 2: with Asymmetry
Constant	0.4611[a] (0.1726)	1.2023[a] (0.1841)
$lcpi_{t-1}$	0.8747[a] (0.0031)	0.8631[a] (0.0034)
lop	0.0225[c] (0.0128)	
lop^{+}		−0.0074 (0.0132)
lop^{-}		−0.0901[a] (0.0198)
$lrgdpc$	0.1025[a] (0.0218)	0.0384[c] (0.0230)
$lreer$	−0.1434[a] (0.0284)	−0.1968[a] (0.0287)
gap	0.0047 (0.0163)	−0.0124 (0.0161)

Numbers in parentheses are asymptotic standard errors. [a,b] and [c] denote significance level at 1%, 5% and 10% respectively

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study examined the non-linear asymmetric relationship between oil price change and inflation for SSA countries by employing a nonlinear panel ARDL (nonlinear PMG). The short and long run oil price changes (oil+ and oil⁻) are introduced into the oil price-inflation model through the positive and negative partial sum decompositions of oil price changes. The study finds that, only the long run positive and negative oil price changes significantly affect inflation while the short run effect is absent. The long run asymmetry is discovered by identifying the unequal or different coefficient values between oil+ and oil⁻ with oil price positive exerting more effect on inflation than its counterpart oil price negative. This simply means, both long run oil price positive and negative changes have significant effect on inflation, but positive oil price change have a greater impact than negative oil price change.

The conclusion that oil prices, positive and negative (oil price^{+} and oil price^{-}) are affecting inflation have a serious policy implication on these (SSA) countries. whenever oil price fluctuates, so also the price level will fluctuate as a result of that. Changes in oil price consequently will be affecting the price level so long as oil remain one of the major production inputs to various sectors of the economy. The price stability as one of the key macroeconomic goals could be attained if these countries can adjust monetary and fiscal measures to withstand the effect of oil price changes on the price level so that stability in the prices of output can be maintained. Understanding the oil price-inflation relationship is very important, as that will pave way to keep the inflation under control. That will enormously help the monetary authorities in designing the suitable policies that can absorb the vagaries of oil price fluctuations. These countries (SSA countries) would understand the oil price-inflation asymmetric relationship so that emphasis should be placed more on the particular change in oil price (here positive change) that affect inflation most, and now macroeconomic policy can specifically be designed more in such a way of tackling positive oil price change than its counterpart. The vast majority of the continent's oil resources are being transported overseas to have a value added and then returned to the countries as refined petroleum products and that is adding extra costs of oversea transportation, other charges which are all going to be borne by firms thereby leading to the increase in the price level. Since, lack of investment, decayed infrastructures and poor performing capacity are the factors that made it necessary for countries across SSA to rely on oil importation to meet up with the growing need of fuel demand, it is vital for these countries to find a way of providing new and efficient refineries and or reviving the existing ones through privatization exercise so that the cost of refined products will be reduced across the countries in the region when the oversea refining costs and other transportation charges are abolished. Privatizing the refineries will bring enormous investment into the sector and that will end the problem of inefficiency, poor infrastructural facilities and capacity underutilization.

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APPENDIX

Appendix I: Countries in SSA region

Appendix II: Map showing low-income and middle-income countries iin Africa

Source: These countries are using the imported refined petroleum products for various manufacturing