Is there Causal Association between Exchange Rate and Inflation in Africa? A Panel Granger Causality Analysis

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1 I am especially grateful for Abrigo for providing me his Stata packages for pvar estimation free of charge.
Abstract

While previous studies have widely demonstrated about the positive relationship between exchange rate and inflation, there is a paucity of scientific evidence whether there exists causation between them and in what direction mostly in developing countries such as Africa. The objective of this study is to empirically examine how changes in exchange rate and inflation interacts over time and empirically examines whether there exists causality between them and in what direction, using a panel data across 26 African countries over the time period 2001-2013. The paper adopts the recent advanced econometric panel VAR model within GMM estimation framework to investigate the causal relationship between the two variables. It also utilizes appropriate panel data unit root and co-integration tests in order to avoid spurious regression results. Exploratory analysis reveals that both variables exhibit similar trends over the long run with a strong positive relationship among sampled countries in Africa. The study shows that exchange rate depreciations have been associated with inflationary pressures across countries in the sample. Panel integration test confirms long-run relationship between them and hence examining causality is relevant. A panel granger causality test also confirms substantial positive relationship with bidirectional causation between the variables of interest. The study draws important policy implication that any monetary policy framework in Africa needs to take into account this feedback effects and address both variables simultaneously.

Key words: Exchange rate depreciation, Inflation, Africa, panel unit root test, cointegration test, panel granger causality analysis, PVAR, feedback effects, monetary policy
1. Introduction

The end of the Breton Woods system around 1973 makes the issue of exchange rate fluctuation very important in macroeconomic policy analysis especially in developing countries, as many developing countries have increasingly opted for more flexible exchange rate regime. Since then, the crucial importance of exchange rate stability in achieving the main objectives of monetary policy (i.e. price stability and economic growth) thereby supporting overall macroeconomic performance mostly in developing countries has been well acknowledged. Indeed, one of the concerns among economists regarding high exchange rate volatility is associated to its inflationary effects (Dornbusch, 1986), given such high volatilities/depreciations have been widely observed phenomenon in the post-Breton Woods flexible regime (Frankel, 1983; MacDonald, 2007) and have been the source of inflationary pressures mostly in developing countries including Africa (Kandil and Mirzaie, 2003; Achsani et al., 2010; Adam, 2009; Mandes, 2013; Lopes et al., eds. 2017). Perhaps, this clues a potential casual association between exchange rate and inflation. Therefore, understanding the behavior of movements as well as the potential causal association between exchange rate and inflation is highly useful for guiding effective implementation of monetary policy. However, there seems to be a paucity of scientific knowledge on such potential causal relationship and direction of causation mostly in developing countries including Africa. This study aims to fill this critical literature gaps.

As has been the trends in other developing countries, the history of exchange rate managements in the post-Breton Woods Africa is characterized by dramatic shifts from highly controlled and fixed exchange rate regime towards more flexible regime (Adam, 2009; Mandes, 2013; Lopes et al., eds. 2017). As noted in the recent study (Lopes et al., eds. 2017), exchange rate targeting is becoming the recent common type of intermediate macroeconomic policy target in Africa with 29 countries out of 54 (54 percent of the total) have implemented it in 2014, and flexible exchange rate regime\(^2\) has emerged as most common regime in Africa, with relatively many countries (20 countries which makes 37% out of the total 54 countries) have adopted it in the

\(^2\) As noted in the book (eds. Lopes et al., 2017), the second important exchange rate regime in Africa in 2014 was intermediate regime, with 18 countries (33 % of total 54 countries) adopted it followed by fixed regime implemented by 16 countries including 14 countries in CFA franc zone in West Africa and the remaining two countries Zimbabwe and Djibouti.
same year. Overall, the greater move towards the floating arrangement has been underpinned following the stabilization and liberalization of programs of the 1980s and 1990s (Gudmundsson, 2010; Adam, 2009). Given most African countries are small open economies, this radical shift away from fixed towards to more flexible regime seems to be surprising and somehow contradict the conventional wisdom (Adam, 2009). This is because both theoretical and empirical evidences suggest fixed or relatively rigid exchange rate regimes are believed to be highly beneficial in terms of stabilizing inflation without hurting economic objectives for low-income and small open economies (Rogoff et al., 2003; Adam, 2009; Joshua et al., 2008). Perhaps, pursuing a floating exchange rate regime becomes more appropriate when these small economies develop and mature.

In evaluating the post-Breton-Woods period, empirical evidences have shown that subsequently depreciation of local currency leads to inflationary situations in many African countries (Adam, 2009; Molana and Osei-Assibey, 2010; Tarawalie et al; 2012; Mandes, 2013; eds. Lopes et al., 2017). According to Adam (2009), this poor performance had very often been linked to the poorly managed exchange rate regimes those countries had pursued in the 1980s and early 1990s. This suggests that managing exchange rate behavior matters for good performance in inflation controlling (i.e. price stability). Furthermore, based on time series data from three African countries (Tanzania, Ghana and Mozambique), Molana and Osei-Assibey (2010) demonstrated that persistent exchange rate depreciation causes exchange rate volatility which intern feed into other variables including volatility in growth and inflation. Perhaps, this is an indication of relationship between exchange rate and inflation in African economies, the least studied issue in the existed literatures and the current paper attempts to address.

While most previous studies in Africa have clearly documented a positive relationship between exchange rate and inflation (see for instance James and Pollin, 2008; Enoma, 2011; Tarawalie et al; 2012), only limited studies have investigated the direction of causation between them (Madesha, 2013) in Zimbabwe, (Adeniji, 2013) in Nigeria, (Lado, 2015) in South Sudan and (Nsiah, 2016) in a panel of 33 African countries. Lado (2015) reported a uni-directional relationship running from exchange rate to inflation whereas the other studies have reported a bi-directional relationship between the two variables in the respective countries. Among existed limited studies in Africa, most of them have been done for country specific cases using a time-
series estimation techniques. A recent study by Nsiah (2016), to our knowledge, is the only study so far that investigates the causal relationship between exchange rate and inflation in a panel data setting on African countries using a PVAR model. Using a PVAR model on a panel data from 33 African countries over the period from, he demonstrated a bi-directional relationship between exchange rate and inflation.

Overall, the preceding discussions reveal that the exchange rate- inflation nexus remains an area of contention in international economics mostly in developing countries such as those in Africa. We believe that the study of causal relationship between exchange rate and inflation for African economies is very essential at least for the following reasons. First, while substantial evidences on the causal relationship among macroeconomic fundamentals including exchange rate and inflation have been well documented in advanced and emerging economies, little is known in African economies (Nsiah, 2016; Madesha et al, 2013). Second, the lack of long-term contracts in developing countries including Africa may suggests a reverse causation as opposed to the implicit assumption in most PPP analysis that suggests exchange rate very often adjusts to price (Nsiah, 2016). Similarly, using time-series data, Molana and Osei-Assibey (2010) have also opined a possibility of reverse causation between depreciation and volatility, where such reverse causation which further weakens the currency can be mitigated by price stability. A further check on this direction of causation utilizing panel data from Africa will greatly contributes to the existing debates on this issue.

Third, recent developments reveal that African countries have shown interest in undertaking inflation targeting and also intervening in the foreign exchange markets (ECA and AU, 2016), thus, understanding this causation is vital for guiding policy design in relation to price stability, and whether credible intervention in the currency market is justified to mitigate the vicious circle of exchange rate depreciation and inflationary pressure. Nsiah (2016) and Khodeir (2012) acknowledge this changing overall trend and emphasis on the key importance of understanding the causation between exchange rate inflation in Africa. Given Africa’s growing importance in the global economy, there is a pressing need to provide latest evidences for an in-depth understanding of the causal association between these two main macroeconomic variables and further broaden understanding on exchange rate policy in Africa.
In light of such conceptual underpinning, the current paper seeks to empirically examine the causal relationship between exchange rate and inflation for 26 African countries over the period from 2001-2013. Indeed, our paper has two main contributions to the literature on exchange rate-inflation nexus in a panel data setting and developing country perspective such as Africa. First, it provides empirical evidence and fills the gaps on the limited knowledge on exchange rate-inflation causation in a panel data setting in Africa. Second, the paper adopts the most recent PVAR model to examine this point of contention on the causation between exchange rate and inflation in developing country perspective and a panel data setting. To our knowledge, no previous studies other than Nsiah (2016) have adopted the panel granger causality estimation techniques in a PVAR model exclusively on exchange rate and inflation on African economies. With this in mind, our study attempts to answer these questions: how exchange rate behaves/moves in relation to inflation? Can stability of exchange rate be attained by taming inflation? Is there a causal association between them and in what direction or do they move independently? A robust analysis of the interaction between exchange rate and inflation is believed to be very supportive for prudent monetary policy formulation in Africa.

This paper is organized in five sections including this introduction. Section two presents a review of related literatures while section three describes the data and methodology employed in the study. Section four discusses the results of the empirical model estimation. Finally, section five concludes and provides some policy insights.

2. Review of Related Literatures

This section attempts to present a brief overview of both theoretical and empirical literatures so as to align the basis for this study with the existing body of knowledge on the subject matter. The review of theoretical literatures provides a synthesis of the different conceptual perspectives underpinning the association between exchange rate and inflation whereas review of empirical
literatures provides evidence on the nature and type of causation between them. It focuses on recent literatures on post-Breton Woods developments.

2.1 The Link between Exchange Rate and Inflation: Theoretical Framework

Standard economic theories suggest that changes in exchange rate and inflation can affect each other. In essence, this may imply the existence of causation between them and this interrelationship could be seen either side, causality running from exchange rate to inflation as well from inflation to the exchange rate. Put simply, on one hand inflation is presented as a determinant of exchange rate (as in PPP theory) and on the other hand exchange rate is considered as external factors influencing inflation through both direct (related to aggregate demand) and indirect (related to aggregate supply) channels.

The monetary theory of exchange rate determination provides a theoretical framework to understand the relationship among monetary fundamentals. The model is gaining increasing application so as to understand the long-run relationship between exchange rate and monetary fundamentals such as inflation, particularly following the collapse of the Bretton Woods systems. The core prediction of the model is that exchange rate is determined in the money market through the interaction of demand for money and supply of money (Frankel, 1983). As Frankel noted, the monetary model of exchange rate determination heavily relies on the string premises of the PPP theory which assumes that there is only one bond and one good in the world. Put simply, PPP condition requires that “the domestic price level is equal to the foreign price level times the exchange rate” (Frankel, 1983, p.87). Given PPP relationship links price to exchange rate, this makes it most important theory within the monetary model framework to explain the relationship between exchange rate and price/inflation. The underlying assumption that PPP is maintained between countries makes it easy to examine monetary variables such as inflation thereby track exchange rate movements by monitoring the monetary variables.

In essence, the monetary model of exchange rate determination consists of two approaches: flexible-price monetary model (following Frankel, 1976) and sticky-price monetary model (following Mundell Fleming, 1962 and Dornbusch, 1976). In these monetary models, exchange rate is viewed as relative prices of two monies (i.e. assets) and shows similar volatility trends with prices. Indeed, such understanding of exchange rate as asset price provides highly useful
opportunities to better understand why exchange rate under the floating regime tends to be much more volatile than economic fundamentals (McDonald, 2007). Although these monetary models rely on PPP and money market equilibrium conditions, they differ in their notions on whether PPP holds continuously. The flexible-priced monetary models states that PPP holds always while fixed-priced monetary model challenges that PPP is maintained only in the long-run and violated in the short run because prices are fixed in the short-run. Unlike the flexible-price model, the sticky-price model assumes that commodity prices are static in the short-run and take time to restore to long-run equilibrium levels. This is well explained in the ‘overshooting model’ of Dornbusch (1976) where its states that short-run equilibrium price appears to exceed the long-run equilibrium price because price in the short run is fixed. According to Frankel (1983), the reasons for short run sticky-price are the presence of contracts, imperfect information and inertia in consumer habits.

As mentioned before, the monetary approach to exchange rate determination states that exchange rate is determined in the money market through the interaction of money demand and money supply. Assuming PPP always holds for identical baskets of goods, the flexible monetary model argues that nominal exchange rate is determined by the relative excess supply of money. Thus, a rise in domestic money supply is accompanied with proportionate change of exchange rate depreciation for PPP to hold continuously. In other words, an increase in money supply in the domestic economy causes price to rise and inflation thereby leads to depreciation of the exchange rate. Similarly, a rise in domestic income (or a fall in expected inflation) causes demand for domestic money to increase and makes the exchange rate to appreciate (Frankel, 1983). While the sticky-price monetary (overshooting) model maintains the same long-run PPP condition holds true like the flexible-price model, an increase in money supply does not lead to a matching change in prices in the short-run because prices remain sticky. According to Dornbusch (1976), a rise in domestic money supply decreases domestic interest rate which creates capital outflows, and subsequently makes exchange rate to depreciate. Thus, the nominal exchange rate is said to be experiencing ‘overshooting’ in the short run.

**2.2 Empirical literatures**

Previous empirical studies have presented mixed results concerning the causation between exchange rate inflation ranging from unidirectional, bidirectional to no causation. Based on a
closer look into these reviewed previous studies, we can organize the review into three forms or
groups, just for the sake of clarity or coherence in presentation. In the first group, we can have
those studies which exclusively dealt with a country-level time series data, which constitutes
most of the reviewed literatures. Among them, many of them reported evidence of bidirectional
causation between the variables of interest (Mandizha, 2014; Madesha et al., 2013; Khodeir,
2012; Philip & Oseni, 2012; Rehman and Aftab, 2015), and few of them documented
unidirectional causation (Laro, 2015) and no causation (Ozor and Eze, 2016). The second groups
includes those studies which have still used country level time-series data but try to consider
causality analysis between different countries in the study and demonstrated mixed results of
causation, both bidirectional and unidirectional (Umar and Dahalan, 2015; Umar and Dahalan,
2016); and other comparative studies across regions (Achsani et al., 2010). The third group
constitutes available studies from panel data settings (Nsiah, 2016). Indeed, this group of studies
is very limited one and it is here we aim to contribute in the literature.

As noted earlier under the first group of studies, most of the reviewed literatures have come from
country level causality analysis and reported bidirectional causation between exchange rate and
inflation. Two studies (Philip & Oseni, 2012; Adeniji, 2013) have reported bidirectional
causality in Nigeria using the same using Co-integration and Multi-Variate Vector Error
Correction Model approach (VECM) but different time periods. Philip & Oseni (2012) examined
the nexus among monetary policy, exchange rate and inflation in Nigeria over the time period
1970-2010. They found a bidirectional relationship between exchange rate and inflation. They
further noted that it is change in exchange rate and inflation that granger caused change in
monetary policy but not the other way round. Thus, they call for the government to keep an eye
on both exchange rate and inflation management for effective monetary policy stance in Nigeria.
Similarly, Adeniji (2013) employed the same VECM method and empirically investigated the
impact of exchange rate volatility on inflation and also applied granger causality test using
annual time series data over the period 1986 – 2012 in Nigeria. He also included other variables
such as money supply, real gross domestic product and fiscal deficit in the model. VECM
estimates demonstrated a strong and positive relationship (significant at 1% level) between
exchange rate and inflation in Nigeria where a 1% rise in exchange rate volatility causes an
increasing inflation by 86.5%. Granger causality test also confirmed bidirectional relationship
between them, implying that exchange rate volatility leads to higher inflation and vice versa.
On the same token, Khodeir (2012) examined the causation between exchange rate and inflation in Egypt to understand the relevance of inflation with exchange rate as the country showed interest towards adopting inflation targeting. Based on monthly time-series data ranging from January 1990 to April 2008, the Granger causality test confirmed the existence of strong positive relationship between the two variables with bidirectional causation.

Mandizha (2014) conducted a granger causality test between inflation and exchange rate depreciation in Zimbabwe using five years data spanning from 2001 to 2005, a period believed to be the core of hyperinflation in the country. The study reported conflicting results of causality in the short-run (within a time period of one to two months) and long-run (two months and beyond). Granger causality test establishes a unidirectional relationship running from exchange rate to inflation in the short-run while bidirectional causation is found in the long-run. Thus, the study underscores the needs for policy makers to disentangle the causal effects along the time periods both for short-run and long-run in order to design more effective monetary policies aims at maintaining inflation and avoiding the chronic depreciation of domestic currency, Zimbabwean dollar. Unlike Mandizha’s findings of a unidirectional causation in the short-run reported for South Sudan, Rehman and Aftab (2015) reported bidirectional causation between the two variables in short-run for Malaysia. The paper adopts an autoregressive distributed lags (ARDL) approach to co-integration and vector error correction model (VECM) and established bidirectional causation running from inflation to exchange rate only in the short run.

Unlike the aforementioned evidences of bidirectional causations between exchange rate and inflation, a unidirectional causation running from exchange rate inflation is documented in a recent study from South Sudan (Lado, 2015). The study uses Granger causality test on monthly time-series data spanning from August 2011 to November 2014. The author has suspicion regarding the absence lack of feedback causality from inflation to exchange rate, and opined that this might have been associated to response of monetary authorities through increasing money supply with the intention to bridge the gap between price and consumer purchasing power thereby protect the low-income group in the economy.

Interestingly, in contrary to what the aforementioned evidences demonstrated some sort of causality (be it unidirectional or bidirectional) between exchange rate and inflation, a recent study from Nigeria reported a result of no causality between exchange rate and inflation in (Ozor
Ozor and Eze (2016) adopted Co-integration test, Vector Error Correction Model and Partial Correlation Coefficient analysis and empirically evaluates the relationship between exchange rate depreciation and inflation over the time period 1980-2013. They recommend for the policy makers to re-visit the exchange rate policy which considers both official and parallel exchange rate markets in order to manage inflation rate. Indeed, as presented above, this result of no causation contradicts to what other studies (Philip & Oseni, 2012; Adeniji, 2013) demonstrated for Nigeria. Stern (2011) argues that estimation results which are unable to reject the null hypothesis of non-Granger causality doesn’t necessarily suggest there is no causality at all. Perhaps, such lack of sensitivity could be associated to ‘a miss specified lag length, insufficiently frequent observations, too small a sample, or the lack of Granger causality even if philosophical causation occurs’ (Stern, 2011; p. 10).

Regarding the second groups of studies, Umar and Dahalan (2015) adopted Toda and Yamamoto dynamic granger causality test and leverage bootstrap distribution theory and examined the causal relationship between real exchange rate and inflation in Malaysia, Nigeria, Philippines and South Africa. Based on annual time-series data from 1980-2012, the study found unidirectional relationship running from real exchange rate to inflation in Malaysia and Nigeria whereas bidirectional relationship was reported in Philippines and South Africa. From policy perspective, the findings suggest that managing inflation rate can stabilize real exchange rate in all countries but stability of inflation can be managed through exchange rate for Philippines and South Africa. The same authors also further investigated the causation between exchange rate and inflation using asymmetric causality approach in addition to Toda and Yamamoto dynamic granger causality test (Umar and Dahalan, 2016).

Umar and Dalahan (2016) further explores the causal relationship between exchange rate and inflation differential in selected emerging economies (i.e. Brunei, Malaysia and Singapore) using quarterly time series data over the time period 1980Q1 to 2015Q1. Unlike previous studies, this study considers the concepts of asymmetric information and attempts to test asymmetric causality in addition to MWALD test based on leverage bootstrapping conducted based on Toda–Yamamoto causality approach. Asymmetric causality test empirically captures the potential variations in causality in both shocks scenarios of positive or good times (exchange rate appreciation) and negative or bad times (exchange rate depreciation), indeed the main
contribution of this study. Accordingly, the asymmetric granger causality test revealed causality running from positive cumulative exchange rate shocks to positive cumulative shocks in inflation differential for Brunei and Malaysia. For Singapore, however, the causality exists running from both times (positive and negative) cumulative inflation shocks to both times (positive and negative) exchange rate shocks respectively. The asymmetric causality test reported no feedback effects between the variables. Obviously, the study has important policy implications for each country. While monetary authorities can monitor exchange rate to stabilize inflation during good times, monetary authorities in Singapore can manipulate domestic inflation to stabilize exchange rate in both good and bad times. However, this result contradicts when causality is tested without taking into account asymmetric information during good and bad times. Without asymmetric effect, the Toda and Yamamoto (1995) MWALD bootstrapped critical values confirm a unidirectional causality running from inflation differential to exchange rate in Brunei and Singapore, but bidirectional causality for Malaysia. They argue that such contradicting outcomes are associated to the existence of size distortion and nuisance parameter estimates when the traditional granger causality method is adopted.

In a comparative study of Asian countries with countries of Europe and North America, a mixed evidence of causation between exchange rate and inflation was reported when estimation was done for the whole sample and separately by regions for Asia vs no-Asia (Achsani et al., 2010). Granger causality test for all countries in the sample demonstrated bidirectional causalities between nominal exchange rate (and also real exchange rate) and inflation. Such feedback causation implies that nominal exchange rate depreciation causes inflationary situations and inflationary pressure leads to depreciation in nominal exchange rate. On the other hand, causality tests by regions revealed opposite unidirectional relationship; causality running from exchange rate to inflation in Asian countries and causality running from inflation to exchange rate in non-Asian countries of EU and North America. The strong impact of exchange rate on inflation suggests that Asian countries have been experiencing higher vulnerability to exchange rate shocks than countries in Europe and North America. The study underscored that managing

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3 Countries used in the study were from Asia (Indonesia, Malaysia, Singapura, Thailand, the Phillipines, Japan, China and South Korea), Europe (United Kingdom, France, Germany, the Netherland, Belgium, Denmark, Sweden, and Norway) and North America (USA, Canada and Mexico). However, the study didn’t disclose the type of model and methodology used to test such granger causality.
inflation can be considered as one of the economy stability indicators in Europe and North America, but the presence of high impacts of exchange rate changes on inflation seems to make managing inflation more complicated for countries in Asia. Thus, the study concluded that managing exchange rate should be considered as main indicator towards achieving inflation targeting for Asian countries.

In the third group of studies, panel data evidences of causation between the variables of interest are reviewed. We have come across two studies that have investigated the panel granger causality between exchange rate and inflation in Africa using different econometric approach, and yet reported similar results of bidirectional causation (Ade and Philip, 2014; Nsiah, 2016). Ade and Philip (2014) adopted a dynamic panel data model based on system GMM and examined the relationship between exchange rate fluctuations macroeconomic performances among SSA countries over the years spanning from 1995 to 2007. The paper also conducted panel cointegration tests using Westerlund statistics as well as bivariate panel granger causality tests between exchange rate and its determinants such as trade openness, interest rate and inflation. They found bidirectional causation between not only exchange rate and inflation but also between exchange rate and interest rate as well as exchange rate and openness. While Ade and Philip (2014) focused on exclusively on SSA countries, Nsiah (2016) considered many counties across Africa. Unlike Ade and Philip, Nsiah adopted the recent PVAR model (following Abigar and Love, 2015) to test panel Granger causality between exchange rate and price level/inflation across 33 African countries over the time period 1990-2014. The application of PVAR model for panel granger causality analysis seems to be on the rise. We are interested to apply this recent econometric PVAR model and further evaluate the panel causation between exchange rate and inflation on a panel of 26 countries in Africa.

In summary, the review of literatures above demonstrates that there are mixed and inconsistent evidences regarding the causal association between exchange rate and inflation. As Umar and Jaharan (2015; 2016) clearly documented, such lack of consistent and conclusive results in the previous studies impede effective implementation of monetary policies. Moreover, despite limited and inconclusive understanding on the causation between exchange rate and inflation in general, most of the available previous studies have documented country level evidence using time-series data, and there seems to be a paucity of knowledge on this causation in panel data
settings. On the other hand, econometric evidence suggests that using panel data is very useful to increase statistical power through larger samples, and hence minimize the small sample size problem linked to using time-series data (Stern, 2011). Nonetheless, there is limited empirical evidence on such causation employing a panel data setting in developing countries and mostly in Africa. Nsiah (2016), to our knowledge, seems to be the only study that adopts a PVAR model and tests PPP for African economies and exclusively examines the causation between exchange rate and inflation in Africa using panel data from 33 countries. In his review of available literatures on PPP in Africa, Nsiah found that none of them considered causation between exchange rate and inflation. This suggests the crucial needs for further studies to broaden the understanding on this debate on the causal relationship between exchange rate and inflation. The aim of this paper is to contribute to this critical gap in the literature on the causation between the two variables using a panel data setting and from the perspective of developing economies.

3. Data and Methodology

This section presents the data sources, empirical model specification and justifications why such particular estimation technique is preferred for this study.

3.1 The Data and variables
The empirical application of a panel VAR model to examine the granger causality between exchange rate and inflation is based on a balanced panel dataset of 26 African countries over the period 2001-2013. For each country, annual time-series data for exchange rate and inflation rate is collected from the WDI online database. We are interested to test causality on a balanced dataset and only countries that have complete data are included in the study. Countries with hyper inflation rate of over 40 are excluded from the study. Our study uses the annual percentage change in both variables. Inflation rate (INFL) is measured as annual percentage change in consumer price index (CPI). Exchange rate (EXRT) is a bilateral official exchange rate between U.S. dollars and local currency in annual percentage change.

Checking the normal distribution of the variables is critical for removing the distortion on estimation results due to some extreme observations. The use of macroeconomic data as annual percentage changes or growth rates to improve the distribution as well as maintain the stationarity of the data seems to be acknowledged. Among others, for instance, Doehr (2015) adopted growth rates of unemployment, interest rate, inflation and exchange rate data on its recent study on “Monetary Policy Expectations and Economic Fluctuations at the Zero Lower Bound”. Doehr (2015) claimed that he adopted growth rates (percent changes) in order to maintain stationarity in the data. We follow the same and adopt both exchange rate and inflation as annual percentage change. Indeed, both normality test/stata estimation results and histogram reveal that inflation rates are normally distributed and don’t need any further transformation to ensure symmetry. The same is also true for exchange rates as annual percentage change (see Figure 1, Annex).

### 3.2 Empirical Methodology

**Justifications of the choice of the empirical estimation model: PVAR**

This paper adopts a panel VAR model to investigate the dynamics of the causal relationship between exchange rate and inflation across sampled countries in Africa. Recently, there is growing interest on the application of a panel VAR model to investigate the dynamics of the

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4 As noted in the acknowledged part (see footnote on the abstract page), this paper has been drafted utilizing a dataset prepared for the study on exchange rate regime and structural transformation in Africa, which constitutes a sub-section under chapter 5 (monetary, exchange rate and other financial policies) of the book mentioned there.
causal relationship between macroeconomic variables in a panel setting seems to be on the rise. A panel VAR model has become a standard econometric to not only analysis the effects of policy transmission but also determine the interactive behaviors among macroeconomic variables. The most silent feature of the PVAR model is that it is a hybrid econometric methodology between the classic panel model and the vector autoregressive model (VAR) (Love and Zicchino, 2006). Thus, it offers the advantage to jointly account for endogeneity issues (as was the case in traditional VAR model) and individual/county-level heterogeneity (associated to panel data structure) (Tiwari, 2011; Belingher, 2015). With this, a PVAR model addresses the limitations of both country level studies using VAR/VECM approach as well as group specific studies using the classic panel data approach based on fixed/random effect/GMM approach/or panel cointegration and Granger causality approach (Tiwari, 2011; Cheratian and Goltabar (2017). Perhaps, the availability of Stata packages to estimate a panel VAR model greatly simplifies the complications in estimating causations in panel data setting and thus attracts interests from researchers. This Stata package was introduced in 2006 by Love and Zicchino and the latest version in 2015 by Abrigo and Love.

Since then, growing studies have adopted this PVAR model to examine the dynamics of the relationship among a diverse of economic variables. To mention some, for instance, Tiwari (2011) analyzed the dynamics of the association of energy sources on economic growth and CO2 emission in Europe and Eurasian countries; Cheratian and Goltabar (2017) on causality between energy consumption and growth of the manufacturing sector in Iran; Boubtane et al (2012) on the interaction between immigration and host economic conditions (i.e. growth and unemployment) in OECD countries; Coulibaly and Kempf (undated) empirically examine the effect of inflation targeting on the exchange rate pass-through to prices in emerging countries; Grossmann et al (2014) explain the dynamic interrelationships between the exchange rate volatility and macroeconomic variables (i.e. GDP, foreign reserve, interest rates and equity index) in 29 countries from developed and developing countries; Tim and Daniel (2015) test for causality in the inequality-freedom nexus for a panel of 100 countries for the 1971-2010 period; Dina and Esengül (2017) investigate the relations of exchange rate and international reserves, money supply and BFCIUS of the Fragile Five countries; Belingher (2015) applied a PVAR model to test the Ricardian approach to deficits in Central and Eastern Europe; Doehr (2015) adopts a panel VAR model to study the “Monetary Policy Expectations and Economic
To sum-up, the preceding discussion demonstrates the increasing application of a PVAR model in recent literatures to analysis the dynamics of the causal relationship between macroeconomic variables. Indeed, this may justify the key advantage of a PVAR model in macroeconomics across different settings including Africa. In the context of Africa, this model provides a novel opportunity to examine the dynamic of the interactive behaviors between economic variables given lack of long time data series in individual countries.

However, as the above brief review indicates, most of the studies have done in advanced economies and the application of this model for developing economies remains less understood. Moreover, while the dynamics of the association between exchange rate and many other macroeconomic variables have been documented, studies that exclusively discuss the causal relationship between exchange rate and inflation are virtually lacking. Nsiah (2016), as far as we know, is the only study that applies a PVAR model and analysis the causation between exchange rate and inflation in a panel of 33 African countries. Thus, the empirical test of this econometric technique in developing economies perspective seems to be at infant stage and needs further study to broaden its application across different economic settings. The aim of this paper is to fill this gap in the literature on the application of a PVAR mode to analyze the causal relationship between exchange rate and inflation in general and from African perspectives in particular.

**Econometric model specification and estimation strategy**

In this paper, we have investigated the causality between exchange rate and inflation based on Granger causality tests. The Granger causality test is commonly applied to check the existing causal relationship between two variables, say unidirectional or bidirectional causality. In our case, this test is used to check whether changes in exchange rate causes inflation changes, or the other way round (i.e. inflation changes derive exchange rate changes). In the language of econometrics, this requires estimation of a Panel Vector Autoregression (PVAR) model.
Following Abrigo and Love (2015), we adopt a panel vector autoregression (PVAR) models in a generalized method of moments (GMM) framework to examine the directions of causations between exchange rate and inflation in 26 African countries. As noted in Abrigo and Love (2015, p. 2), the model entails the following system of linear equation with a k-variate panel VAR of order p with panel specific fixed effects.

\[ Y_{it} = Y_{i,t-1}A_1 + Y_{i,t-2}A_2 + \cdots + Y_{i,t-p+1}A_{p-1} + Y_{i,t-p}A_p + \chi_{it}B + \mu_{it} + \varepsilon_{it} \quad (1) \]

where, \( Y_{it} \) is a (1xk) vector of dependent variables - EXRT and INFL; \( \chi_{it} \) is a (1x1) vector of exogenous covariates; \( \mu_{it} \) is a (1xk) vector of dependent variable -specific fixed-effects; \( \varepsilon_{it} \) stands for a (1xk) vector of idiosyncratic errors; \( A_1, A_2, \ldots, A_p \), and \( B \) are (kxk) and (lxk) matrices respectively, which are the parameters required to be estimated. Assuming: \( E[\varepsilon_{it}] = 0, E[\varepsilon_{it}'\varepsilon_{it}] = 0 \) and \( E[\varepsilon_{it}'\varepsilon_{st}] = 0 \) for all \( t > s \).

In the presence of lagged dependent variable as explanatory variable, a GMM framework has been proposed as a good estimation technique to produce consistent estimates of the general panel VAR model including the aforementioned equation (Roodman, 2009; Abrigo and Love (2015). After transformation of the above equation, the GMM estimator can be represented as follow (Abrigo and Love, 2015):

\[ A = \left( \bar{Y}'Z\bar{W}Z'\bar{Y}' \right)^{-1} \left( \bar{Y}'Z\bar{W}Z'\bar{Y}' \right) \quad (2) \]

where, \( \bar{W} \) is a \((LxL)\) weighting matrix assumed to be non-singular, symmetric and positive semi-definite. Very often the weighted \( \bar{W} \) is used to maximize efficiency. It is assumed that \( E[Z'e] = 0 \) and rank \( E[\bar{Y}'Z] = kp + l \). Given this GMM estimator is said to be consistent, Abrigo and Love (2015) suggest that the panel Granger causality test can be performed using this GMM estimates. Based on the GMM estimates of \( A \) and its covariance matrix, the Granger causality can be inferred from the Wald tests of the parameters.

The system of endogenous variables included in our model is exchange rate (EXRT) and inflation (INFL). Our interest here is to investigate the causality between exchange rate and
inflation. Therefore, after estimating the above \textit{pvar} model (equation 1) using GMM techniques, we conducted the Granger causality tests (using \textit{pvargranger} stata command), as used in Abrigo and Love (2015).

4. Results and Discussion

This section presents the results of the study. It starts with descriptive or exploratory analysis in order to understand the behavior and interaction of the panel data over time. With the aid of simple graphs, we explore the co-movement between exchange rate and inflation over time among sampled countries in Africa. We also briefly discuss test results for stationarity and cointegration mainly to avoid spurious regression that may create potential bias in the causality test. Finally, we will present results from panel granger causality test between the exchange rate and inflation and discuss the policy implications.
4.1 Descriptive/Exploratory Analysis

We first check for normality tests. Both normality test result and histogram reveal that there is no issue of skewness and the variables resemble those of a normal distribution (see Figure 1, Annex). Thus, we use both variables as percentage changes and no need to log transform. This has been the practice by some studies.

Table 1 (see Annex) presents a summary statistics of the data used in the analysis. A closer examination of the data reveals that exchange rate and inflation are moving together in a positive relationship (Figure 2). Results from bivariate correlation between inflation and nominal exchange rate also reveal a strong correlation at 1% significant level. Exchange rate depreciations have been associated with inflationary pressures in sampled African countries (see Table 2, Annex). Indeed, this result is consistent with previous empirical studies in a panel data in Africa where they report a positive relationship between exchange rate depreciation and inflation (Lopes et al., 2017; James and Pollin, 2008). Moreover, our result suggests that those countries with higher inflation very often experience higher rate of currency depreciation in relation to the currencies of their major trading partners. This happens because higher domestic inflation rates increases the relative prices of exports and decrease the relative prices of imports. This ultimately reduces the purchasing power and depreciation of the currency. In short, a high inflation tends to be followed by currency depreciation.

Figure 2: Relationship between changes in exchange rate and inflation, 2001-2013

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5 The author of this paper involved as chapter co-author in this book.
Table 1 also shows that the degree of fluctuation or volatility in the two variables also vary across the exchange rate regimes (fixed, intermediate and flexible). It discloses that on average the change in both variables tend to follow the same direction. Given other things constant, lower level of volatility of the nominal exchange rate seems to be accompanied by lower level of fluctuation in inflation. In line with the theories, inflation volatility tend to be lower under fixed regime (3.5) compared to intermediate (6.09) and floating (9.05) regimes. Similarly, fixed exchange rate regime has lower depreciation rate (5.37) than intermediate and floating regimes.

Table 1: Change in exchange rate and inflation by exchange rate regimes (mean estimation), 2001-2013.

<table>
<thead>
<tr>
<th>Exchange rate regime</th>
<th>Rates of depreciation and inflationary pressure by regimes</th>
<th>Overall volatility level by regimes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exchange rate</td>
<td>Inflation</td>
</tr>
<tr>
<td>Fixed</td>
<td>5.37</td>
<td>4.27</td>
</tr>
<tr>
<td>Intermediate</td>
<td>9.93</td>
<td>6.46</td>
</tr>
<tr>
<td>Floating</td>
<td>9.86</td>
<td>9.38</td>
</tr>
</tbody>
</table>

Source: Own computation based on WDI, 2015.

### 4.2 Panel Unit Root and Cointegration Tests Results

Given the primary motive of this study is to apply a PVAR model for panel Granger causality test, model specification for panel unit root and cointegration tests is not included in the methodology section. Only test results are presented.
Before running panel VAR model estimation, it is very essential to account for non-stationarity as well as cointegration of the data used in the model. This process is critical to avoid spurious or misleading estimation results regarding the type and nature of dynamic interactions between economic variables. Panel unit root tests are employed to check the stationarity of the data while the long-run relationship is checked using panel cointegration test. Thus, we checked for both before estimating the panel VAR for model for estimating granger causality tests.

Panel unit root test constitutes an important first step in panel granger causality analysis is to ensure that the panel data are stationary so as to guide meaningful predictions. This process is very important to inform by identifying the level of integration of the variables of interest. Given our balanced panel data, we use panel unit root tests that require balanced sample such as Lin, Levin, and Chu (2002) and Im, Pesaran, and Shin (2003). The Lin, Levin, and Chu (2002) test assumes a common unit root process while Im, Pesaran, and Shin (2003) assumes individual unit root processes. In both LLC and IPS, the null hypothesis is that each series in the panel has unit root (non-stationary). However, there seems to be a bit variation how the alternative hypothesis is specified between LLC and IPS. In the alternative hypothesis, LLC test demands stationarity of all panels with common or same autoregressive coefficient but the IPS test requires that some of the individual series to contain unit roots with different autoregressive coefficients. In short, LLC assumes common unit root process whereas IPS assumes individual unit root process.

Table 4 (see Annex) documents the results from panel unit root tests based on the two estimation procedure; LLM and IPS. Given our data which are given as annual percentage change, both LLC and IPS strongly rejected the null hypothesis that both variables contain unit roots. Thus, both exchange rate and inflation are found to be stationary at 1% level of significance. Such stationarity of the variables at annual percentage change series implies that the two variables may exhibit long run relationship.

Apart from identifying the stationarity status (order of integration) of each series in the panel, determining whether the panels exhibit long-run relationship is also important in order to avoid spurious regression results for our causality analysis. This requires panel cointegration tests to check if there is long-run relationship between integrated series. We follow a recent study by
Nsiah (2016) and adopt Westerlund (2007) panel cointegration tests. Westerlund (2007) specifies the null hypothesis of no cointegration based on results from four panel tests. Rejecting the null hypothesis implies that there is cointegration (long-run relationship) between the variables of interest.

We checked whether there is long-run relationship between exchange rate and inflation movements using panel co-integration tests on the panel VAR to ensure that inference is based on nonspurious relationships. Table 5 (see Annex) reports the results of panel cointegration tests based on Westerlund (2007). According to the results, all the four panel test statistics reveals a strong rejection of the null hypothesis of no cointegration in the Westerlund (2007) error-correction model. Thus, the result confirms that indeed there is strong long-run relationship between movements between nominal exchange rate and inflation across sampled countries in Africa. This implies that the two variables share a common trend and long-run equilibrium for sampled countries in Africa. In essence, our finding is consistent with the monetary model of exchange rate theory (such as PPP) which states a stable long-run relationship between nominal exchange rate and price levels/inflation. Recently, Nsiah (2016) also reports evidence of strong long-run relationship between nominal exchange rate price differences among 33 countries in Africa. With this in mind, we can now proceed with the examination of the dynamics of the causal relationship between the variables of interest.

4.3 Panel Granger Causality Analysis

As noted earlier, the aim of this study is to investigate the strength and direction of the causation between exchange rate and inflation across African countries in the sample. More specifically, it attempts to determine if exchange rate movements precede corresponding inflation movements across countries. The previous result on evidence of strong long-run relationship between our variables of interest suggests the needs to further investigate the nature and type of causal relationship between them. Obviously, presence of long-run relationship doesn’t tell us anything about the directions and magnitudes of causation between the two variables. In the language of econometrics, this demands us to further test for panel granger causality to determine the

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directions of the association. Therefore, we perform a panel pairwise granger causality tests on a pvar$^8$ model for this purpose using ‘pvargranger’ stata command as noted in Abrigo and Love (2015).

Furthermore, we checked whether the chosen pvar model is stable and produce efficient estimation results for the causality analysis. Stability conditions tests for such PVAR also confirms that selected panel VAR is stable as reflected in the modulus of each eigenvalue which is strictly less than one (Table 7 and Figure 3, Annex).

We then precede to the analysis of the estimation results from the panel granger causality test. The result of the panel granger causality test is reported in Table 8. The causality tests confirm bidirectional causal relationships between exchange rate and inflation across sampled countries in Africa. Indeed, the result is consistent with recent study by Nisah (2016) in African context.

As a matter of fact, such bi-directional causation has fundamental policymaking implications. The causality from inflation to exchange rate implies that stabilizing exchange rate in the long-run requires policy makers to keep inflation low. Perhaps, this is important policy measure in most developing countries as it is hardly possible to use foreign capital inflows (other policy that can help stabilize exchange rate) as a means for exchange rate management. On the reverse causality from exchange rate to inflation, keeping exchange rate low helps have a stable inflation over the long-run. Overall, there is a need for policymakers to take note of such feedback effects when designing monetary policy.

Table 8: Panel Granger causality test results

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$^8$ As noted in Abrigo and Love (2015), this model selection is guided by estimation results from pvarsoc. We prefer one lag order based on MBIC (see Table 6 Annex).
panel VAR-Granger causality Wald test
Ho: Excluded variable does not Granger-cause Equation variable
Ha: Excluded variable Granger-causes Equation variable

<table>
<thead>
<tr>
<th>Equation \ Excluded</th>
<th>chi2</th>
<th>df</th>
<th>Prob &gt; chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXTE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFL</td>
<td>7.077</td>
<td>1</td>
<td>0.008</td>
</tr>
<tr>
<td>ALL</td>
<td>7.077</td>
<td>1</td>
<td>0.008</td>
</tr>
<tr>
<td>INFL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXTE</td>
<td>9.487</td>
<td>1</td>
<td>0.002</td>
</tr>
<tr>
<td>ALL</td>
<td>9.487</td>
<td>1</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Source: Own compilation based on WDI 2015.
5. Conclusion and Policy Implications

This paper empirically examines the causal association between exchange rate and inflation across 26 countries in Africa over the time period 2001-2013. The panel Granger causality test was performed in a panel VAR model within a GMM estimation technique, as proposed in Abrigo and Love (2015). Efforts have been made to investigate the behavior of movements in exchange rate and inflation as well as the potential causation and direction of causation them across a panel of sampled countries in Africa. The paper also applies relevant panel unit root and cointegration tests have been done in order to avoid spurious regressions that could create potential biases in the Granger causality test results. With this, the paper contributes to the limited empirical literatures on the area of interest in a panel data setting and developing countries perspective by taking Africa as a case study.

Both descriptive and econometric estimation results demonstrate that there is strong positive relationship between exchange rate and inflation among sampled countries in Africa. The behavior of movements in exchange rate and inflation appear to be similar over the long-run. Consistent to the literatures, the paper finds that incidences of exchange rate depreciations have been associated with inflationary pressures in sampled countries. The study confirms that correlation indeed implies causation. The panel Granger causality test reveals a substantial causality between the two variables with bidirectional causal relationships. This suggests that there exists feedback effects between them and any policy intervention on one of them will affect each other.

The feedback effects have fundamental policy importance in Africa. The causality running from inflation to exchange rate implies that keeping exchange rate at a competitive level highly requires keeping domestic inflation low and needs to be aligned with international inflation. On the reverse causation which runs from exchange rate to inflation suggests that a monetary policy that aims to maintain price stability strongly demands maintaining exchange rate at low level. Therefore, the main policy recommendation of this paper is that African policy makers needs to take note of such feedback effects between exchange rate and inflation and try to address them simultaneously while designing monetary policy.
Reference


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Coulibaly, Dramane and Hubert Kempf, 2013. Does Inflation Targeting Decrease Exchange Rate Pass-through in Emerging Countries?


Gudmundsson, Mar. 2010. “The choice and design of exchange rate regimes”.


Stern, David I., 2011. “From Correlation to Granger Causality” Crawford School of Economics and Government, Australian National University, Canberra


Annexes

Annex

Figure 1: Distribution of exchange rates and inflation rates (annual percent change), 2001-2013

In addition to the histogram, Stata reports the probability that the skewness of the variables resemble those of a normal distribution. As noted in adjusted chi2 and p-value, both the kurtosis and skewness are of those of the normal distribution.

Table 1: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFL</td>
<td>7.026527</td>
<td>6.329138</td>
<td>-9.616154</td>
<td>36.96476</td>
<td>N = 338</td>
</tr>
<tr>
<td></td>
<td>within</td>
<td>5.239595</td>
<td>-9.59899</td>
<td>36.33729</td>
<td>T = 13</td>
</tr>
<tr>
<td></td>
<td>between</td>
<td>3.615251</td>
<td>1.704938</td>
<td>15.36643</td>
<td>n = 26</td>
</tr>
</tbody>
</table>

| EXTE     | 2.653672 | 10.63399  | -28.23327| 43.91023 | N = 338      |
|          | within   | 9.850069  | -29.32565| 39.39432 | T = 13       |
|          | between  | 4.080533  | -2.541141| 10.78982 | n = 26       |

Table 2: Correlation matrix (pwcorr EXRT INFL, sig)

<table>
<thead>
<tr>
<th></th>
<th>EXTE</th>
<th>INFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXTE</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>INFL</td>
<td>0.4027</td>
<td>1.0000</td>
</tr>
<tr>
<td></td>
<td>0.0000</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: Summary of Panel Unit Root Test Results (Appendix)

<table>
<thead>
<tr>
<th>Variables</th>
<th>LLC</th>
<th>IPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>p-value</td>
</tr>
<tr>
<td>EXRT</td>
<td>-10.3722</td>
<td>0.0000</td>
</tr>
<tr>
<td>INFL</td>
<td>-9.4099</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Source: Own computation based on WDI, 2015.

Table 5: Panel co-integration test result

Calculating Westerlund ECM panel cointegration tests.......... 

Results for H0: no cointegration  
With 26 series and 1 covariate  
Average AIC selected lag length: 1.77  
Average AIC selected lead length: .23  

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Z-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gt</td>
<td>-13.544</td>
<td>-71.035</td>
<td>0.000</td>
</tr>
<tr>
<td>Ga</td>
<td>-37.412</td>
<td>-19.558</td>
<td>0.000</td>
</tr>
<tr>
<td>Pt</td>
<td>-22.661</td>
<td>-13.846</td>
<td>0.000</td>
</tr>
<tr>
<td>Pa</td>
<td>-20.695</td>
<td>-10.023</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Source: Own computation based on WDI, 2015

Table 6: Lag selection

Selection order criteria  
Sample: 2005 - 2012  
No. of obs = 208  
No. of panels = 26  
Ave. no. of T = 8.000  

<table>
<thead>
<tr>
<th>lag</th>
<th>CD</th>
<th>J</th>
<th>J pvalue</th>
<th>MBIC</th>
<th>MAIC</th>
<th>MQIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.5383572</td>
<td>36.09368</td>
<td>.0003129</td>
<td>-27.95678</td>
<td>12.09368</td>
<td>-4.100673</td>
</tr>
<tr>
<td>2</td>
<td>.639445</td>
<td>18.24768</td>
<td>.0194443</td>
<td>-24.45262</td>
<td>2.247685</td>
<td>-8.548547</td>
</tr>
<tr>
<td>3</td>
<td>.3467531</td>
<td>7.09368</td>
<td>.1310234</td>
<td>-14.25654</td>
<td>-.9063917</td>
<td>-6.304508</td>
</tr>
</tbody>
</table>

Source: Own computation based on WDI, 2015
Table 7: Stability condition for PVAR

<table>
<thead>
<tr>
<th>Eigenvalue</th>
<th>Real</th>
<th>Imaginary</th>
<th>Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>.2756719</td>
<td>.2245336</td>
<td></td>
<td>.3555423</td>
</tr>
<tr>
<td>.2756719</td>
<td>-.2245336</td>
<td></td>
<td>.3555423</td>
</tr>
</tbody>
</table>

All the eigenvalues lie inside the unit circle. pVAR satisfies stability condition.

Figure 3: Stability condition for PVAR