THRESHOLDS EFFECT OF MONEY GROWTH AND INFLATION IN RWANDA: A NONLINEAR VAR MODEL

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ABSTRACT

This paper estimated the threshold value of money growth and inflation as an early warning indicator for shifts in the inflation regimes, using quarterly data for Rwanda during the period 2007 to 2020. The Nonlinear VAR methodology allows us to capture possible nonlinearities such as asymmetric reactions to shocks and empirically test for changes in the relationship between money growth and inflation. The estimated threshold value is approximated at 15.3 percent for the money growth indicator (M3) in the case of headline inflation while the threshold value is equivalent to 17.1 percent on core inflation. The estimated values split the data into two regimes, the inflationary stressful episode, and the non-inflationary stressful episode. The findings revealed that switching from one regime to another regime provides a better signaling probability on the ex-post inflation that could be the basis of the forecast of the future path of inflation. We also presented the historical decomposition from the TVAR to the contribution of the four identified shocks on both cases of headline and core inflation. The overall results obtained support the view that money growth provides timely warning signals of transitions between inflation regimes. Thus, money growth provides an important early warning indicator to the risks of the departure of inflation from price stability.

Keywords: Inflation, money supply, Threshold VAR
JEL classification: E52, E63, E64

1. INTRODUCTION

The prime role of most central banks around the world is to achieve stable economic growth by maintaining low and stable inflation; it is also commonly believed that inflationary flows create macroeconomic instability, and the emergence of this phenomenon poses a serious threat to policy making.

The existence of a positive relationship between money and prices is well agreed upon in the economic literature. A large consensus can be found on both the direction and the dimension of the effect of an increase in the monetary aggregate on price developments. The statement that, in equilibrium, monetary policy is neutral hinges on the quantity equation which in turn defines a positive one-to-one relationship between monetary and price growth over a long-term horizon. On the other hand, others have posited that money serves as a useful crosscheck for monetary policy analysis and remains an important determinant of long-term inflation. The economic profession, however, highlights that, money is not the sole cause of price developments in the short run and that a certain value must elapse before the one-to-one relation emerges, the neutrality may not hold over shorter horizons.

The studies conducted in most countries on whether the relationship is linear or non-linear implies that money growth and inflation are consistently positively related and money plays a crucial role in balancing the price level. Nelson (2003) and Gerlach (2004) argue that money contributes to the understanding of inflation dynamics and should, thus, remain an integral part of modern monetary policy. Since the National Bank of Rwanda switched to a price-based monetary policy framework, it is important to determine a threshold level of money growth, which acts as a 'warning signal' of the departure from the price stability goal using the threshold vector autoregressive (TVAR) model. This is a widely used technique for estimating non-linear relationships among macroeconomic time series. The discussion applies to a wide class of popular non-linear structural vector autoregression models, such as the TVAR, STVAR, TVP-VAR, and Markov-Switching VAR, to mention a few.

The previous studies mainly applied the traditional time series analysis based on linearity assumptions; however, the real-world issues do not adhere to linearity assumptions and may not adequately characterize the dynamics that we are looking for. This paper contributes to the modern monetary policy literature and policymaking in at least three ways. First, to determine a threshold level of money growth which acts as a 'warning signal' of the risk of the departure of inflation from the price stability regime by trying to evaluate ex post the leading properties of money growth for price dynamics. Second, we try to disentangle the regimes that may turn an increase in money growth to suddenly raise the inflation, which may help the National Bank of Rwanda to distinguish inflationary from non-inflationary episodes of sustained monetary expansion. This signaling probability contains a valuable piece of information to forecast inflation at a specific horizon within the given regime, supporting other toolkits used by the National Bank of Rwanda to respond adequately to inflationary risks and succeed in maintaining price stability.

Third, we explore a historical decomposition of shocks (HD) for the proposed TVAR model. This allows us to differentiate which of the macroeconomic shocks (implicit in our TVAR system) were the main determinants of the behavior of the economy by estimating the magnitude of the contribution of each shock and the relative roles played by exogenous and endogenous shocks.

The remainder of this paper is organized as follows, after the introduction; a review of relevant literature is presented in section 2. Section 3 discusses the methodology and data. Section 4 reports the empirical results, and discussions of results. Section 5 presents conclusion and policy recommendations.

2. LITERATURE REVIEW

2.1 View of inflation in various economic doctrines

The theoretical foundations of this research are based on the viewpoints of economic doctrines on inflation and emphasizing non-linear inflationary dynamics. Classical economists were the first to put forward the theory of money inflation; they considered that monetary factors were able to completely explain inflation. Their theory of economic literature is known as the "quantity theory of money." Fischer, through his equation of exchange, explained inflation on a monetary basis, then Marshall looked at the "quantity theory of money" from the Cambridge doctrine. After that, in a new form of the quantity theory of money, Friedman articulated his interpretation of the quantity theory of money as a theory of demand for money. In addition, the followers of this doctrine, considering the conditional expectations of the formation of inflationary expectations based on past information, believe that monetary policies in the short run will affect the level of production and other real variables, but in the long term, they will make money neutral.

In the rational expectation model, it is also highlighted that the person does not just look at the past information in forecasting inflation, but uses all the available data for prediction, including the past experience and information on the expected future state serves all the available data for prediction. Furthermore, people do not make systematic mistakes in their predictions. Regular errors are easily discovered and corrected over time, and the way of shaping their expectations varies in the same way. The new classics, who believe in the formation of expectations based on rational expectation, argue that monetary policies are both neutral in the short run and the long run, only unforeseen monetary policies affecting real variables in the short term.

The theory of demand-pull inflation also perceives the cause of the rise in inflation as the increase in demand. Increasing demand could be driven by an increase in investment and autonomous consumption, expansionary fiscal policy, expansionary monetary policy, declining money demand, and improving trade balance. John Maynard Keynes (1939) offers his argument that inflation prevails if the demand for consumer goods exceeds supply at full employment level, then this excess demand creates an inflationary gap and prices rise so much that this gap is filled. In the cost-push inflation theory, contrary to the doctrine of money and the Keynes doctrine, the imbalances in the supply sector, and in particular, the increase in the cost of production and transmission of the total supply curve is the main reason for rising prices.

The structuralist view indicates that inflation is likely to develop due to the state of unbalanced economic, political, and cultural structures. Various and often complex factors play a role in creating and sustaining this inflation. In analyzing the inflationary dynamics, attention to the process of its linear or nonlinear behavior is of particular importance because the existence of extreme volatility and uncertainty in the behavior of some economic variables such as inflation due to the nature of these variables can lead to economic instability in society.

Therefore, the existence of these uncertainties causes behavioral inflation that is based on nonlinear functions, not considering the nonlinear behavior of economic variables causes an error. Therefore, the use of linear models to investigate and explain the influence of other economic variables on inflation cannot reveal the realities of the economy altogether.

2.2. Theoretical derivation of money and inflation

This section sets out a minimum model of the determination of prices to emphasize the role of monetary factors in the inflation process. Time should be thought of as being measured in quarters since monetary policy is assumed to have short-run inflationary effects. Let us begin our analysis with a Phillips curve of the form:

$$\pi_{t+1} = \pi^{e}_{t+1,t} + \alpha_y \left(y_t - y^*_t \right) + \alpha_z z_{t+1} + \varepsilon_{t+1} \quad \text{.........} \quad (1)$$

Where $\pi_t \equiv 4\Delta p_t \equiv 4\left(p_t - p_{t-1}\right)$ is the annualized inflation rate in the quarter t, p_t is the price level, $\pi^{e}_{t+1,t}$ is expectations in the quarter t, of inflation in the quarter $t+1$ (which we specify further below) y_t is output, y^*_t is potential output, $y_t - y^*_t$ is the output gap, z_t is an exogenous variable, or shift factor (for instance, a supply shock) (we discuss the dating of the exogenous variable further below), and ε_t an iid "cost-push" shock, and where $\alpha_y \succ 0$

In P^* models (Hallman, Porter and Small,1991 and Reimers,1994) inflation is instead assumed to be governed by

$$\pi_{t+1} = \pi^e_{t+1,t} - \alpha_p \left(p_t - p_t^* \right) + \alpha_z z_{t+1} + \varepsilon_{t+1} \quad \text{.. (2)}$$

Where $\alpha_p \succ 0$. Thus, the P^* model replaces the output gap with the negative of the "price gap," $p_t - p_t^*$ as the key determinant of inflation (Some of the literature in monetary economics have defined the price gap with the opposite sign, as $p_t^* - p_t$).

Here p_t^* the long-run equilibrium (LRE) price level, denotes the price level that would result with the current money stock, provided output is at potential and velocity at its long-run equilibrium level. Thus, p_t^* is defined as:

$p_t^* \equiv m_t + v_t^* - y_t^*$, where m_t is the money stock (in empirical work typically M2 or M3), $v_t \equiv p_t + y_t - m_t$ its velocity, v_t^* is the LRE velocity, which is specified further below. While the micro-foundations of the P^* models are not clear (to us, at least), the model has been used to account for the behavior of prices in several countries and is typically seen among proponents of monetary targeting as providing a theoretical rationale for focusing on policy deliberations on the behavior of monetary aggregates.

For these reasons, we use P^* a model setup here. Since we focus on the role of monetary aggregates, it is informative to follow Svensson (2000) and express the P^* model in terms of the real money gap, $\tilde{m}_t - \tilde{m}_t^*$, where

$\tilde{m}_t \equiv m_t - p_t$, is real money balances and $\tilde{m}_t^* \equiv m_t - p_t^* \equiv y_t^* - v_t^*$ is LRE real money balances.
Since the real money gap is the negative of the price gap:

$$\tilde{m}_t - \tilde{m}_t^* \equiv \left(m_t - p_t\right) - \left(m_t - p_t^*\right) = -\left(p_t - p_t^*\right) \quad \text{.. (3)}$$

We can then write the P^* model as:

$$\pi_{t+1} = \pi^e_{t+1,t} + \alpha_m \left(\tilde{m}_t - \tilde{m}_t^*\right) + \alpha_z z_{t+1} + \varepsilon_{t+1} \quad \text{.. (4)}$$

Where $\alpha_m \equiv \alpha_p \succ 0$, the P^*model consequently assigns a crucial role to the real money gap as a predictor of future inflation, analogous to the role of the output gap in traditional Phillips curves. One immediate consequence of this is that to the extent the P^*model accounts for the behavior of inflation, the real money gap i.e nominal money growth is the natural indicator of future inflation.

2.3. Empirical literature

As previously discussed, the monetarist theory has been empirically tested and gained extensive support during the Ronald Reagan and Margret Thatcher regimes in the U.S. and U.K. Similarly, the importance of money supply was recognized by the Bank of Japan in the 1970s, when the Bank began announcing forecasts for money growth (Assenmacher-Wesche et al., 2008). However, in later years, Monetarism was subject to criticism, with economists such as Kaldor (1985) and Tobin (1981), questioning the assumption of the homogeneity of the money supply. Many subsequent studies showed that velocity did not remain stable, leading to an unstable short-run relation between money supply and inflation (Estrella and Mishkin, 1997; Stock and Watson, 1999; Gerlach and Sevensson, 2003).

Following these studies, several empirical studies provide support for a strong link between money growth and inflation. Using spectral analysis, Benati (2009) shows that there has been an almost one-for-one, relatively stable relation between long-run money growth and the rate of inflation in the U.S. and U.K. over the last two centuries. Crowder (1998) also finds a strong long-run relationship between money growth and inflation. The trend growth component in inflation as measured by the consumer price index (CPI) is found to be explained completely by the trend component of the monetary base growth.

DeGrauwe and Polan (2005), also testing the quantity theory of money relation for a sample of 160 countries over a period of 30 years using Ordinary Least Squares (OLS) and fixed effects estimation, observe a strong positive link, however, not proportional relation, between long-run inflation and the rate of money growth. They, however, find that the strong link between inflation and money growth is driven by the group of high inflation countries in the sample. De Grauwe and Polan

(2005) find that the relationship between inflation and money growth is weak for low-inflation countries.

More recently, Amisano and Fagan (2013), employing a Markov Switching model and Bayesian methods on data from the euro area, Germany, the U.S., the U.K., and Canada, find that money growth is an important predictor of price shocks. Employing a multivariate state-space model to investigate the effect of money on prices in the U.S., El-Shagi, and Giesen (2013) also observe a significant effect of money growth on prices in the U.S. Canova and Ferroni (2010) examine the monetary policy–inflation relation in the U.S. employing a structural model and Bayesian estimation methods. They find that policy shocks explain inflation volatility; however, the effectiveness of policy in generating changes in inflation has fallen over time. Similar evidence is documented by Canova and Menz (2012) for Japan.

Amisano and Colavecchio (2013) investigate the non-linearity in the pass-through from money supply to inflation in a Bayesian Markov Switching framework for the U.S., the U.K., the Euro area, and Japan over 1960–2012. They find evidence of a nonlinear relation between money growth and inflation. The non-linearity is attributed to different monetary regimes. The link between money growth and inflation is found to be strong during the high-inflation periods of the 1970s and 1980s, and weak during low inflation periods.

Reynard (2012) examines the inflation paths of countries during normal times and periods of financial crises. He argues that the inflation paths of countries depend on the response of monetary aggregates to these crises. Studies suggest that monetary aggregates contain important information for predicting changes in inflation and that the quantity theory is still alive (Teles and Uhlig, 2013).

The following table presents selective empirical findings of some studies with a different database, monetary variables, and time. Most of them employed cross-section data on a group of countries for some time for homogeneous countries. While others use time-series data, examining the correlation of money supply and inflation in a single country for a long time. The common monetary variables that are often employed in the chosen papers are M1, M2, and M3. The general conclusion that can be drawn from the surveyed articles is that, as postulated by the monetarist, most authors detected a long-run impact of changes in money supply on inflation rates. Nevertheless, most papers ignored all other possible determinants of inflation and concentrated only on money growth in the analysis as the main determinant of inflation.

Table 1: Survey of selected studies on the linkage between money supply and inflation

Author	Monetary Variable	Sample	Period	Main Findings
Us (2004)	Base money (Mo)	Turkey	1990:01–2002:04	No relationship
Altimari (2001)	M1, M2 & M3	Euro Area	1980-1997	Positive relationship
Diouf (2007)	Broad money	Mali	1979:1-2006:1	LR and SR correlation
Pindiriri (2012)	M3	Zimbabwe	2009-2011 (monthly)	Positive
Jones & Khilji (1998)	M1 & M2	Pakistan	1973 to 1985	Positive
Nikolic (2000)	M3, M2, Mb & Mo	Russia	1992-1998	Weak correlation
Darrat (1986)	Narrow money	North Africa	1960-980 (quarterly)	Positive
Thornton (2008)	Money in circulation, M1 and M2	African economies	1960-2007	Weak for counties with inflation and money growth below 10%
Drevall&Ndung'u (2001)	M1&M2	Kenya	1974 – 1996	Exist only in the short run
Simwaka et.al (2012)	M2	Malawi	Monthly (1995-2007)	Positive relationship
Morana& Bagliano (2007)	M1, M2 & M3	USA	1959:1- 2003:2	Positive long run correlation
Kabundi, A (2012)	M3	Uganda	Monthly (1991-2011)	Positive
Akinbobola (2012)	M1 & M2	Nigeria	1986:1-2008:4	Positive
Zhang (2012)	M2	China	1980 -2010	Positive

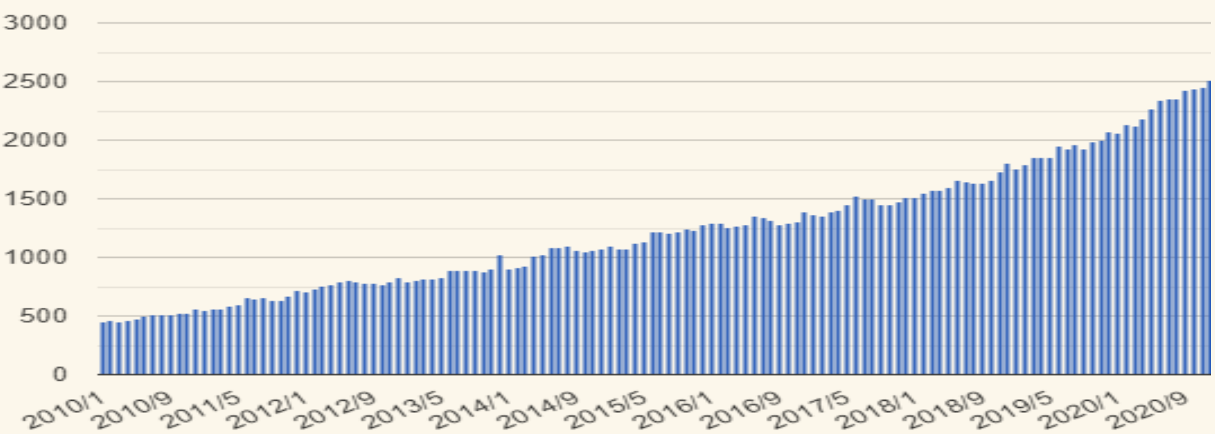
Source: Author's literature survey

2.4. Money supply and inflation developments in Rwanda

Over the past two decades, the paces of price increases in Rwanda have been kept at moderate levels. However, to manage inflation is no easy task, because there are other factors uncontrolled by the monetary policy like drought which leads to the shortage of food production and supply and changes in international price situations (like that of crude oil) among others. This is in contrast to the monetarist view, which states that inflation is always and everywhere a monetary phenomenon. For the broad money indicator (M3), we provide data for Rwanda from January 2010 to February 2021 to see the historical evolution of monetary developments.

The average value for Rwanda during that period was 1253.11 billion Rwanda Franc with a minimum of 452.06 billion Rwanda Franc in March 2010 and a maximum of 2560.75 billion Rwanda Franc in February 2021.

Figure 1: Evolution of money supply in Rwanda



Source: TheGlobalEconomy.com

On other hand, in 2020, the inflation rate for Rwanda was 6.9 percent. Though Rwanda's inflation rate fluctuated substantially in recent years, it tended to decrease through the 2001 - 2020 period ending at 6.9 percent in 2020. This is in line with the monetary policy objective of attaining price stability while ensuring sustainable economic growth through the means of monetary policy.

Figure 2: Evolution of inflation in Rwanda

Source: IMF: World Economic Outlook (WEO)

3. METHODOLOGY AND DATA

3.1. Methodology

This paper follows the approach used by Balke (2000) and Li and St-Amant (2008) to study money growth and inflation using a threshold vector autoregression (TVAR) to test whether the relationship between money growth and inflation shifts when the level of money growth reaches a certain (threshold) value. The TVAR models are part of an increasingly rich literature of non-linear models which have developed from the switching regression model (Quandt, 1958). The TVAR models have been applied in post-industrial economies (see Balke, 2000) who tests the effects of credit regimes on the amplitude of business cycles in the United States, Altissimo and Violante (2000) who test for threshold effects in the relationship between unemployment and output in the United States, and Atanasova (2003) who tests for credit regime effects on business cycle amplitudes in the United Kingdom.

The choice of the TVAR model has several interesting features: First, it is a relatively simple way to capture possible nonlinearities such as asymmetric reactions to shocks or the existence of multiple equilibria (which, in a time-series context, might be reflected in multimodal stationary distribution). Secondly, the variable by which different regimes are defined can itself be an endogenous variable included in the VAR. Therefore, this makes it possible that regime switches may occur after the shock to each variable. As the effects of the shocks are dependent on both the initial conditions, along with the sign and size of a shock and the impulse response functions are no longer linear, it is possible to identify the disparities between the high inflation and low inflation episodes under development of money supply.

The threshold VAR can be specified as follows:

$$Y_t = \alpha^1 + \beta^1(L)Y_t + \left[\alpha^2 + \beta^2(L)Y_t\right]\mathrm{I}(S_{t-d} \succ \delta) + \left[D^1 + D^2\mathrm{I}(S_{t-1} \succ \delta)\right]U_t \quad \text{..................... (5)}$$

where Y_t is a vector of endogenous variables, U_t are the structural residuals, and are assumed to be normally distributed and independent, each of unit variance. The lag polynomial $\beta^i(L) = \beta_1^i L + \beta_2^i L^2 + \dots \beta_p^i L^p \; i \in \{1,2\}$ represents VAR parameters associated with the two regimes. The matrices D^1 and D^2 map the structural residuals to the reduced form residuals in both regimes.

The function I takes on the value of 1 when the threshold variable S_{t-d} exceeds the critical threshold value of δ, and 0 otherwise. Because the matrices D imply a regime-dependent mapping between the reduced form residuals and the structural residuals, this also implies regime-specific covariance matrices.

Balke identifies the four shocks using a Cholesky ordering in the order that I introduced the variables. This is an identification assumption and implies the D matrices will be lowering triangular. I similarly take $d = 1$, as per the original paper. The TVAR can thus be described as two locally linear VARs, whose dynamics can be described by the parameters with the superscript 1 if the threshold variable is below the threshold, and the additional terms kicking in when the threshold variable is above the threshold. The lag order p is set to 4, as per the rule of thumb. For the linear model, it is relatively straightforward to understand that the impulse responses in such a case will remain constant over the given time, simply because the covariance structure does not vary over time. Additionally, impulse responses in a linear model can be derived directly from the estimated coefficients and the estimated impulse response shocks are thus correspondingly symmetric in terms of size, persistence, and sign (Af#nso et al., 2011). However, when moving on to discuss the non-linear model, the complexity inevitably increases given we cannot repeat such assumptions as the same properties will not necessarily hold (Koop, Pesaran & Potter, 1996). In a typical nonlinear case, we appraise whether the economic dynamics diverge across the different regimes and then examine the size, persistence, and sign of an impulse shock response function to see if they differ from one regime to another. The non-linear impulse response function in contradiction to the linear impulse response function is more complex, and is given by the following function:

$$NLIRF = \mathrm{E}\left[Y_t + k \mid \Omega_t - 1, \varepsilon_t\right] - \mathrm{E}\left[Y_t + k \mid \Omega_t - 1\right] \quad \text{.. (6)}$$

In the function, $\Omega_t - 1$ denotes the data set at the given time $t-1$, and ε_t is the exogenous shock. The function design indicates that we have to condition the sign and the size of the shock, with consideration to the history of the variables in the model (Balke, 2000).

Look at the conditional expectations from the non-linear impulse response function, which are given by $\mathrm{E}\left[Y_t + k \mid \Omega_t - 1, \varepsilon_t\right]$ and $\mathrm{E}\left[Y_t + k \mid \Omega_t - 1\right]$ must be estimated while simulating the model, according to the estimation procedure presented by Balke (2000):

Firstly, to be able to create the simulated forecast series, we draw the shock effects from the starting period 0 to q of the residuals of the estimated threshold vector autoregression model and thereafter for each respective initial value of the residual, which means that each point of our data sample is utilized through our model. After that, we condition the resulting forecast series on the specific sequence of the initial values and the shocks and by doing so the simulation will return one given an estimation of $\left[Y_t + k \mid \Omega_t - 1\right]$.

Following this, we repeat the simulation conducted in the first forecast using the same residuals and initial values. However, we modify the function to let the shock of the focused variable be fixed to ± 2 standard errors or ± 1 standard error at the given time $t = 0$. Thus, the second simulation returns one estimate of the function $[Y_t + k \mid \Omega_t - 1]$.

Next, we compute the difference between the first and second estimation, which returns one simulated value for our nonlinear impulse response function. To ensure that any potential asymmetries which could arise due to sampling variation in the drawn shocks are removed, the procedure will be with 500 iterations. As a result, the average of these 500 nonlinear impulse response function calculations provides our estimated nonlinear impulse response function (Balke, 2000; Af#nso et al., 2011 and Atanasova, 2003).

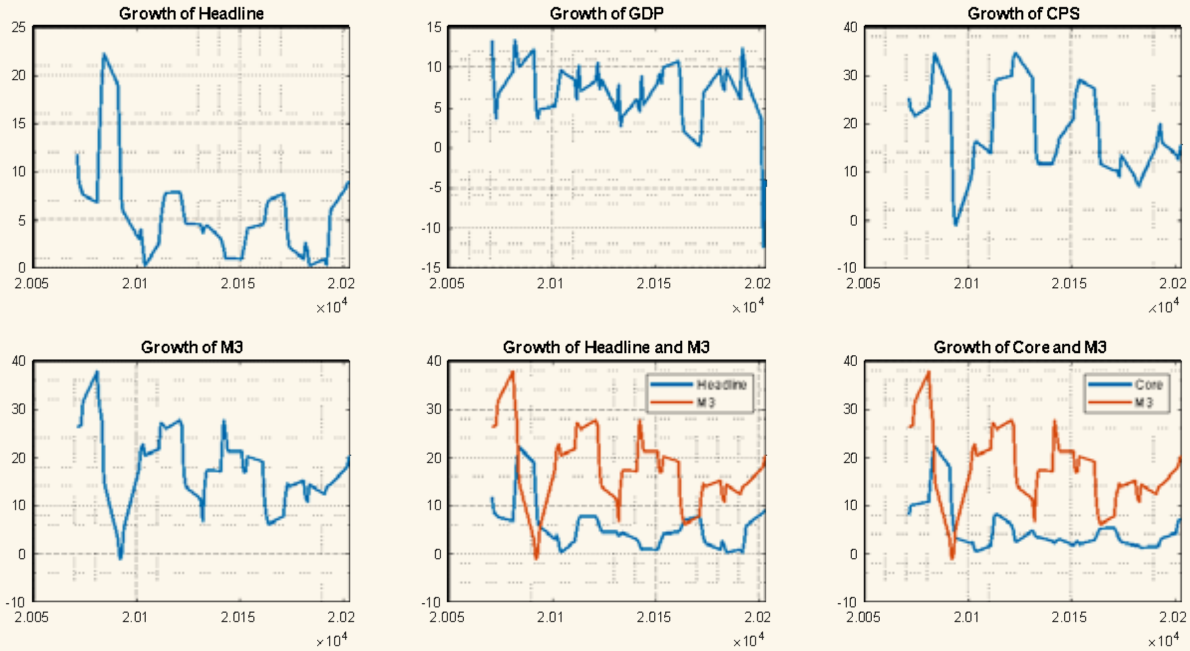
3.2. Data presentation

Before delving into the workings of the empirical estimation, it may be helpful to offer a small overview of the data gathering process. This paper uses quarterly time series spanning from 2007 to 2020. The variables considered for this study are the indicator of money supply (M3), Consumer Price Index (CPI) for the inflation rate, Real Gross Domestic Product (RGDP), and Credit to Private Sector (CPS).

We therefore, present results based on the four shocks, which are labeled as output shock, credit shock, price shock, and money shock. The growth in money supply is used as the threshold variable. All the variables come from the National Bank of Rwanda.

We plotted the quarterly percentage change annualized in broad money and inflation rate data together to observe the pattern of movement in these two variables. As per Figure 1, it can be seen that there are consistencies in the movement of money supply and inflation rate. An increase in the money supply also leads to a spike in the inflation rate. This shows that there is a pattern in the movement of money supply and inflation rate.

Figure 3: Sample data visualization



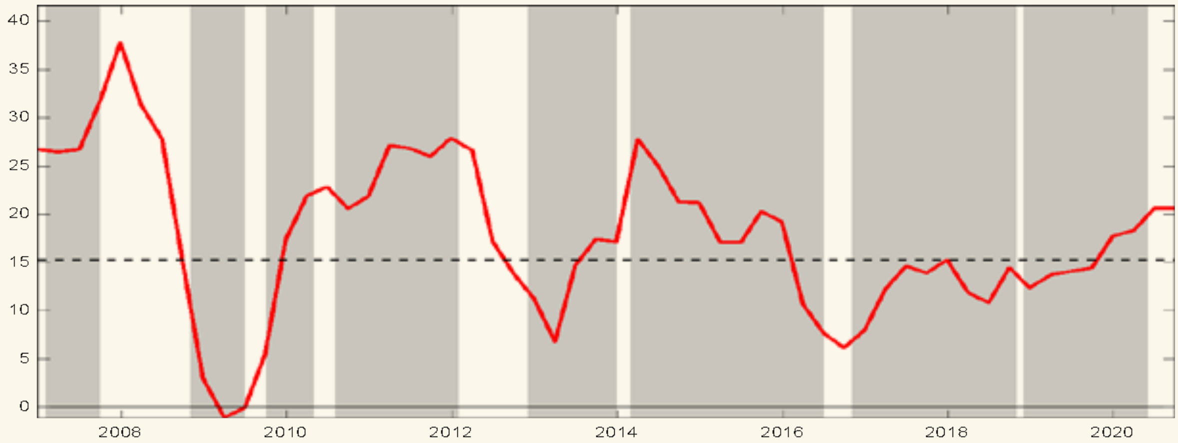
Source: Author's computation

We believe that the non-linear behavior of inflation suggests that linear modeling is not able to explain the changes in inflation, and the use of non-linear time series models can provide a better interpretation of the inflationary dynamics based on different regimes. Also, the non-linear behavior of inflation can indicate the difference in the speed of convergence towards the inflation target in the economy. Hence, with the understanding of the above patterns of movement in broad money and inflation, we move further into developing a TVAR model for further analysis.

4. EMPIRICAL ANALYSIS AND RESULTS

In this section, we present the estimated threshold values from the TVAR model on headline inflation and core inflation separately. Following the process outlined by Hansen (1996), the results show a p-value of 0.000 for the calculated Wald-statistic, strongly confirming the suspected presence of non-linearities and providing support for the use of the two regime threshold VAR model. We perceive the money growth as a threshold variable to present a flavor of the two inflation regimes or episodes as proposed by Balke (2000). The inflation rises in the expansion of money growth, and most of the observations in the high inflation regime or episode coincide with NBR monetary expansion.

Figure 4: Estimated threshold value of money growth and headline inflation

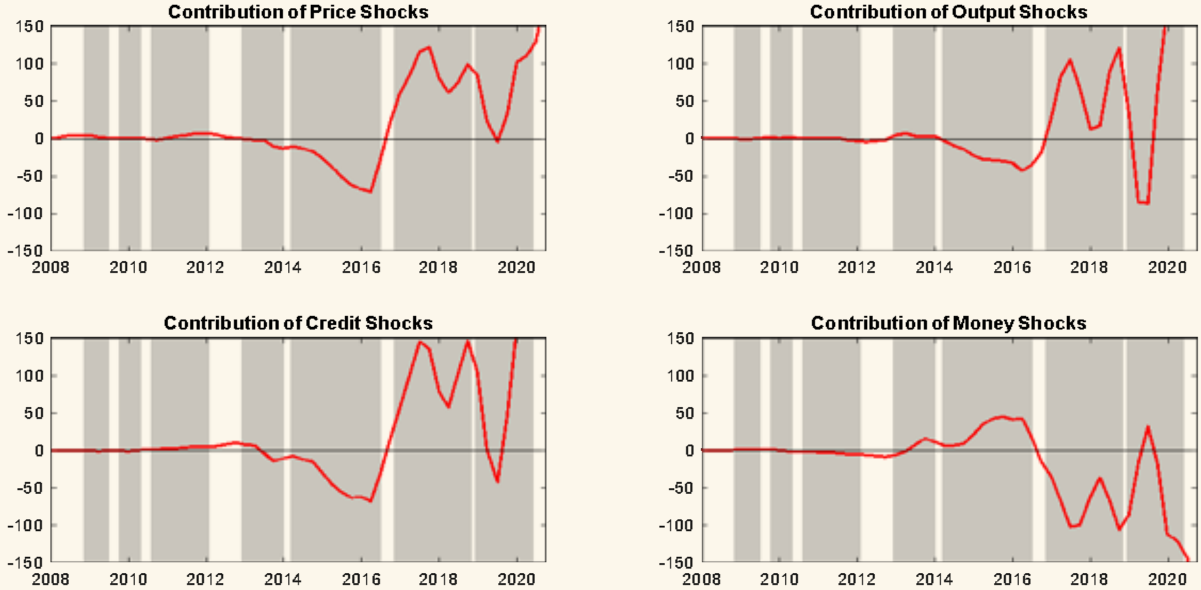


Source: Author's estimation

The estimated threshold value is approximated at 15.3 percent for the money growth indicator (M3), following the procedure outlined in the section of methodology. This means that our model estimates Rwanda to be in the inflationary episode when the money growth is above 15.3 percent. Thus, the estimation divides the data into two regimes, in the inflationary regime, which is the state of an inflationary stressful time, and in the non-inflationary regime, which is the regime with the state of a non-inflationary stressful time. As we can see from the plotted graph in figure 4, the estimated threshold value appears to offer a good estimator for historically tracking inflationary stressful time and non-inflationary stressful time.

It is straightforward to verify under a linear VAR, the change in forecast function (CFF) can be analytically evaluated, and is identical to the historical decomposition for linear VAR models. Analogously, the remainder in a linear VAR model is zero by construction. The CFF generally does not have an analytical form in non-linear models and is often evaluated numerically using Monte Carlo integration, such as Koop, Pesaran, and Potter (1996). In non-linear models, the remainder emerges because the non-linearity causes the contributions of shocks and the forecast to not add up. The remainder can thus be interpreted as the extent that the nonlinearity interacts with the shocks.

Figure 5: Historical decomposition and change in forecast function of headline inflation from TVAR



Source: Author's estimation

Figure 5 above presents the historical decomposition of money growth from the TVAR to the contribution of the four identified shocks. Following Balke (2000), we also plot the CFF, but he uses a horizon of 12 quarters to compute the CFF. For us, we consider the entire sequence of shocks as this is the only construction wherein a linear VAR model, the CFF is equivalent to the historical decomposition and the remainder from the CFF is zero. Thus, we are evaluating the CFF in a manner much closer to the conditional structural decomposition by Kilian and Vigfusson (2017).[2]

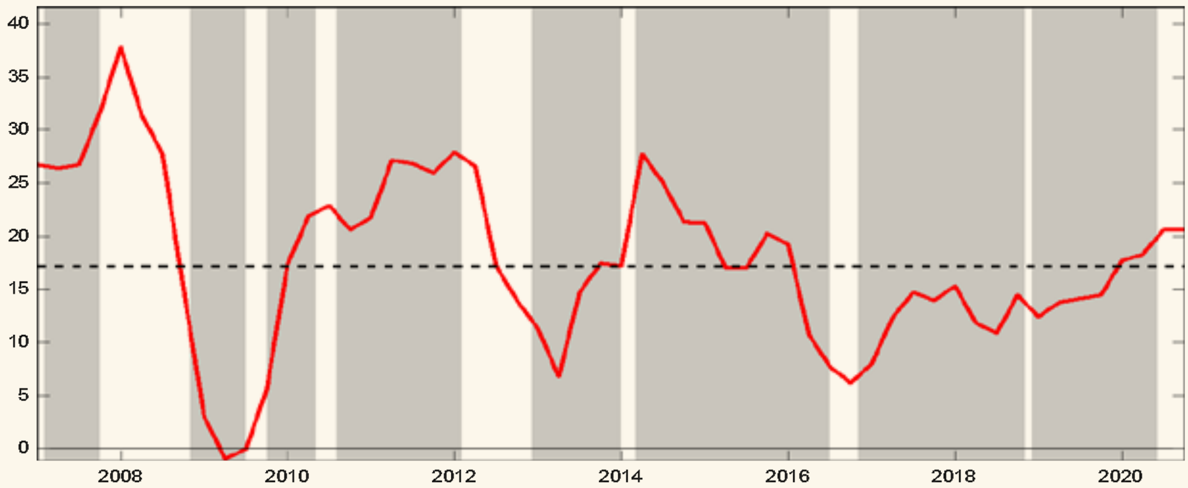
While there are many similarities between the historical decomposition and the CFF, the divergences between the two are most prevalent during or around the contraction. This is not surprising as the threshold, which is the source of the non-linearity, tends to kick in during expansion (see Figure 4). This can also be seen by observing the remainder term evidencing its largest variations during and around expansion, which can be interpreted as when the non-linearity is being particularly relevant in propagating shocks. Even if the remainder term in the CFF is useful in

[2]To ensure that any remainder calculated in our empirical work is due to the non-linearity interacting with the shock, and rules out the possibility that the remainder may be picking up the effect of a shock that has a high level of persistence. Note though that if the model's propagation mechanism is not extremely persistent, choosing a sufficiently long horizon, such as 12 quarters, may provide a sufficiently good approximation.

understanding when the non-linearity is particularly relevant for propagating shocks, it does not decompose these fluctuations induced by the non-linearity to contributions by any particular shocks.

However, the above-presented findings show the model output for both the high inflationary regime and low inflationary regime as estimated by the TVAR model for the case of headline inflation. It is prime to consider also the core inflation which captures the direct effect of monetary policy.

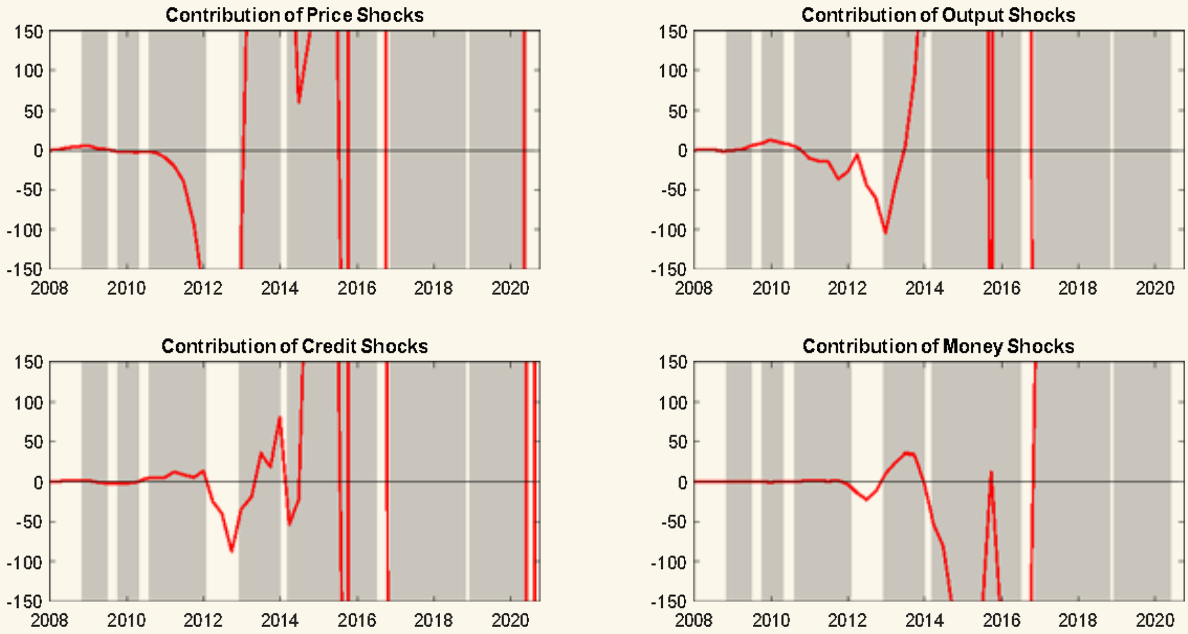
Figure 6: Estimated threshold value of money growth and core inflation



Source: Author's estimation

We keep following the same step to estimate the threshold value between money growth and core inflation. The result is quite meaningful and supports the economic theory with the threshold value of 17.1percent greater than 15.3 percent on the headline inflation. Thus, the conduct of monetary policy should focus on core inflation that is, a measure of inflation that excludes the rate of increase of prices for certain volatile components in price indexes, even if the monetary policy is capable of controlling overall inflation in the long run, it cannot fully control relative price movements such as those for food and energy.

Figure 7: Historical decomposition and change in forecast function of core inflation from TVAR



Source: Author's estimation

The measures of core inflation attempt to strip out or smooth volatile changes in particular prices to distinguish the inflation signal from the transitory noise. Thus, relative to changes in headline inflation measures, changes in core measures are much less likely to be reversed, provide a clearer picture of the underlying inflation pressures, and so serve as a better guide to where headline inflation itself is heading. Of course, if a particular shock to non-core prices is not temporary but, rather, turns out to be more persistent, then the higher costs are likely to put some upward pressure on core prices. Moreover, the forecast horizon set is the same as in the case of headline inflation, so that the change in forecast reflects shocks that occurred over the same quarters. Keeping in mind the usual caveat about interpreting reduced-form time-series models, linear or nonlinear, a few interesting episodes stand out in figure 6, not surprisingly, because the feedback from the headline is smaller compared to the case of core inflation, the direct link between monetary development and core inflation is still substantial.

5. CONCLUSION

Building on the existing literature that establishes a long-run link between inflation and money growth, this paper has estimated the threshold value of money growth and inflation as an early warning indicator for shifts in inflation regimes, using quarterly data for Rwanda during the period 2007 to 2020. The non-linear VAR methodology allows us to capture possible non-linearities such as asymmetric reactions to shocks and empirically test for changes in the relationship between money growth and inflation. The discussion applies to a wide class of popular non-linear structural vector autoregression models, such as the TVAR, STVAR, TVP-VAR, and Markov-Switching VAR, to mention a few. We modeled inflation as a process characterized by two regimes: non-inflationary and inflationary in which the probability of shifting from one regime to the other depends on a measure of money growth.

The estimated threshold value is approximated at 15.3 percent for the money growth indicator (M3) in the case of headline inflation. This means that our model estimates Rwanda to be in the inflationary episode when the money growth is above 15.3 percent. Thus, the estimation divides the data into two regimes, in the inflationary regime, which is the state of an inflationary stressful time, and in the non-inflationary regime, which is the regime with the state of a non-inflationary stressful time. Moreover, it is prime to consider also core inflation which captures the direct effect of monetary policy. We keep following the same step to estimate the threshold value between money growth and core inflation. The result is quite meaningful and supports the economic theory with the threshold value of 17.1percent greater than 15.3 percent on the headline inflation.

This result is striking on monetary growth above the estimated thresholds; we expected a much higher correlation with prices. However, findings suggest that the predictive capacity of monetary aggregate for headline inflation dynamics may be weaker compared to the core inflation consistently with the modern theory of the monetary policy. Thus, the conduct of monetary policy should focus on core inflation that is, a measure of inflation that excludes the rate of increase of prices for certain volatile components in price indexes, even if the monetary policy is capable of controlling overall inflation in the long run, it cannot control relative price movements such as those for food and energy. We also presented the historical decomposition of findings from the TVAR to the contribution of the four identified shocks on both headline and core inflation. Bearing in mind that the usual caveat about interpreting reduced-form time-series models, linear or nonlinear, a few interesting episodes stand out in historical contribution of the shocks on headline and core inflation is not surprising, because the direct link between monetary development and core inflation is still substantial.

The overall results obtained support the view that money growth provides timely warning signals of transitions between inflation regimes. Although, the signals coming from money growth are considered noisy. This caution aside, we believe that the results are sufficiently robust supporting the claim that money growth is a leading indicator of shifts in the inflation regime.

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