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**MONETARY POLICY TRANSMISSION MECHANISM IN
BOTSWANA: A TIME-VARYING PARAMETER VAR APPROACH**

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ABSTRACT

This study examines the evolution of Botswana's monetary policy transmission mechanism by employing a time-varying parameter model. Botswana provides a good context for assessing the transmission of monetary policy over time, following structural and macroeconomic reforms since 1989. The time-varying parameter vector autoregressive (TVP-VAR) model with stochastic volatility is employed for quarterly time series data from 1994Q1 to 2018Q4. The study evaluates how the responses of real non-mining output and price levels to the Bank Rate, exchange rate, and credit shocks changed over time. The paper contributes to the literature by capturing the time-varying nature of the underlying structure of the monetary policy and the economy of Botswana. The empirical results indicate that real output, inflation, and exchange rate responses to monetary policy shocks changed over time under the study period, confirming the time-varying nature of monetary policy transmission for Botswana.

1 INTRODUCTION

Economic research is increasingly focusing on attempts to identify the contribution of monetary policy shocks to the economy over time. Monetary policy shocks are often used as a policy instrument to counter economic instability such as unstable inflation rates (Acosta-Ormaechea and Coble, 2011). Maintaining economic stability largely depends on the substantial role and the efficacy of policy instruments, and the evolution of the monetary policy transmission mechanism. While the literature on the monetary policy transmission mechanism is mature, researchers face some challenges and often fail to account correctly for them when they examine the transmission mechanism. One of the main challenges is the change in relationships among economic variables over time, which is as a result of structural breaks such as recessions and economic and financial reforms in an economy (Mies and Tapia, 2003). That is, the structural changes that occur as an economy reforms can change the inter-relationships amongst the macro-variables within the country and, in turn, alter the transmission mechanism. This could result in the misinterpretation of a country's monetary policy efficacy. According to McKinnon (1973), financial and macroeconomic reforms largely influence economic activity and aim to establish an active financial sector that is able to accommodate a more efficient monetary policy transmission mechanism.

The extensive empirical literature measuring monetary transmission mechanism, for instance, Bredin and O'Reilly (2001); Dabla-Norris and Floerkemeir (2006); and Ngalawa and Vieg (2011), bases its analysis on constant parameters and ignores the time-varying nature context. There is scant evidence in Africa on the time-varying aspect of monetary policy transmission mechanism (Mwabutwa, Bittencourt and Vieg, 2013; Owusu-Sekyere, 2017). However, there have been numerous studies on the monetary policy transmission mechanism that have studied the time-varying nature of parameters but have mostly concentrated on developed economies (for example, Korobolis, 2010; Nakajima, Kasuya and Watanabe, 2011; Liu, Song and Huang, 2019). These studies postulate that economic structure and the relationship between variables change over time, which may also alter the monetary transmission mechanism. As such, a time-varying parameter model gives accurate empirical results as it reduces the researcher bias caused by significant deterministic shifts. As it is important to include the time-varying nature based on these studies, we need to analyse

this for African countries, and most especially for Botswana. Previous work on Botswana's monetary policy transmission (Kganetsano, 2007; Setlhare, 2013) has focused on the unrestricted Vector Auto-Regressive (VAR) and Structural VAR estimations, respectively. As argued by Primiceri (2005), traditional VAR models have been subject to price puzzles¹ and spurious dynamics in random coefficients as they fail to assess how changes in the way macroeconomic variables respond to shocks evolve over time.

Since 1989, the Botswana economy has been characterised by prevalent events, such as economic and financial transformation between 1989 and 1994. Subsequently, financial liberalisation and the evolution of a more competitive and robust financial sector emerged. The conduct of monetary policy has also evolved, as the predominant strategy of the Central Bank of Botswana since 2002 focused on maintaining price stability and sustainable economic development. Moreover, the establishment of the Botswana Stock Exchange in 1994, the removal of capital controls, and rapidly increasing credit facilities have meant that the financial sector has deepened. Exchange controls were also relaxed, giving rise to the introduction of the crawling band exchange rate in 2005 (Bank of Botswana, 2012). Furthermore, Botswana's monetary transmission process was changed by the Central Bank's move from direct to indirect tools of monetary regulation from 1991, as well as the adoption of a medium-term inflation target/objective from 2002 to date. For these reasons, Botswana provides a good context for assessing the transmission of monetary policy over time, following structural and macroeconomic reforms (which amount to financial liberalisation) since 1989.

The objective of this study, therefore, is to investigate the time-varying characteristics of monetary policy shocks in Botswana over the past 25 years amidst the economic and monetary policies' general institutional and structural changes. This is based on the research question: To what extent have structural reforms in the economy and the monetary policy framework affected the monetary policy transmission mechanism? We employ the Bayesian Time-varying Parameter Vector Autoregressive (TVP-VAR)

¹ A phenomenon whereby inflation rises in response to a monetary policy tightening, which is contrary to economic theory is a price puzzle (Kganetsano, 2007).

techniques by Primiceri (2005) and Nakajima and Watanabe (2011) for the period from 1994Q1 to 2018Q4.

The contribution of this study is that, unlike most previous studies which ignored time-varying effects, it investigates the time-varying structure of the economy and monetary policy transmission in Botswana through its use of the TVP-VAR model. This dynamic model delivers more accurate empirical results by reducing researcher bias from deterministic shifts (Koop and Korobilis, 2010). The TVP-VAR model has an added benefit over other models, as it does not require to split data into subsamples to verify the change of the structure of the model (Nakajima and Watanabe, 2011). Moreover, the Bayesian technique provides unbiased estimates and valid inferences in small sample sizes by preserving parsimony, given the relatively short period covered in this study (Primiceri, 2005). The limitation of most traditional models is that their coefficients are time-invariant; whereas, in actuality, the structure of the economy and the relationship between variables change over time.

To the best of our knowledge, this is the first study to assess the monetary policy transmission in Botswana while allowing for the time-varying nature of parameters. By applying the TVP-VAR technique, we can better obtain the dynamic effects of monetary policy and provide more robust and up-to-date information on the efficacy of the monetary policy transmission process for Botswana, thus adding to the limited existing literature. The results show significant time-varying features. Specifically, the results show that the transmission of monetary policy following reforms performed in line with predictions of economic theory and for most of the study.

The remainder of this study is structured as follows: Section 2 presents an overview of Botswana's economy and the monetary policy framework. A review of the relevant literature is discussed in Section 3 while Section 4 is dedicated to data and discussion of the method. The empirical results are analysed in Section 5, and Section 6 serves as the conclusion.

2 OVERVIEW OF BOTSWANA'S MONETARY POLICY FRAMEWORK AND ECONOMY

This section discusses the monetary policy framework for Botswana. Until 1989, the financial sector in Botswana was heavily regulated. The central bank, that is, the Bank of Botswana, set interest rate ceilings for lending rates and a floor for deposit rates, and also inhibited movement of capital through the use of capital controls (Kganetsano, 2007). The restrictive measures mostly resulted in negative real interest rates for deposits which discouraged investment and stunted economic growth in turn. These regulations also resulted in a lack of competition, leading to a lack of efficiency, in the financial system (Kganetsano, 2007). In 1989, the central bank introduced a financial liberalisation programme which not only increased competition but also enhanced efficacy in the financial system.² The financial liberalisation programme let the market operate more efficiently. This ensured that policy actions by the Bank of Botswana were transmitted through the economy quickly and effectively.

Since 1991, the Bank of Botswana (BoB) has indirectly influenced the level of market interest rates, such as deposit and lending rates, through adjustment of the Bank Rate and by engaging in open market operations (which involves the sale and purchase of Bank of Botswana Certificates (BoBCs) introduced in 1991). These reforms amount to financial liberalisation. From the early 1990's, the goal of the interest rate policy shifted to that of maintaining real interest rates that promote savings and ensuring that loans are channelled chiefly to productive purposes such as investment. These monetary policy reforms have implications for the interest rate trajectory and macroeconomic variables; the reforms therefore have an overall impact on the monetary transmission mechanism in Botswana. For instance, an efficient financial sector (particularly the banking sector) is instrumental in ensuring that funds are directed towards efficient investment which, in turn, stimulates output growth. In addition to these developments, the BoB started using Primary Reserve Requirements in 1994, and moral suasion in 2000 to influence monetary conditions and hence the inflation rate (Bank of Botswana, 2012).

² Banks, the pension and insurance industry, and the Botswana stock exchange have since grown over the years based on this development strategy and Botswana's economic stability (Bank of Botswana, 2012).

Subsequent to a time of direct controls on interest rates, the current monetary policy framework comprises the use of BoBCs and the Bank Rate to control demand and, ultimately, achieve the inflation objective. During the period of financial repression, the objective of price stability was not distinctly specified. The precise focus on the goal of price stability in Botswana commenced in 2002. At that time, the main aim of BoB's monetary policy was "to achieve price stability, which is defined as a sustainable level of inflation that is within the objective initial range of 4-6 percent" (Bank of Botswana, 2012). From 2008, to date, the price stability objective was broadened, and it has been defined in terms of inflation within the medium-term objective³ range of 3-6 percent (Bank of Botswana, 2012). Maintaining low and expectable inflation rates, and favourable financial conditions fosters effective investment and economic expansion.

Movements in the Bank Rate, credit to the private sector and inflation between 1994Q1 and 2018Q4 are shown in Figure 1. The figure shows a significant spike in inflation in 2006Q2 in line with the introduction of restrictions on the purchasing of BoBCs by commercial banks and an excess demand in the economy. The spike could have also been due to the 12% devaluation of the Pula in the first quarter of 2005. There was also a notable increase in inflation in 2008, owing to increased excess demand, a surge in credit, and the substantial increase in world oil and food prices. Moreover, inflation movements seem to have followed the Bank Rate. This is consistent with theory and the mandate of BoB to use interest rates to influence demand, and, ultimately, price developments in the desired direction. Both inflation and the Bank Rate were relatively high in 2006 and 2009. This was against a background of the implementation of the crawling band exchange rate policy in 2005 and the 2008/09 financial crisis, respectively.

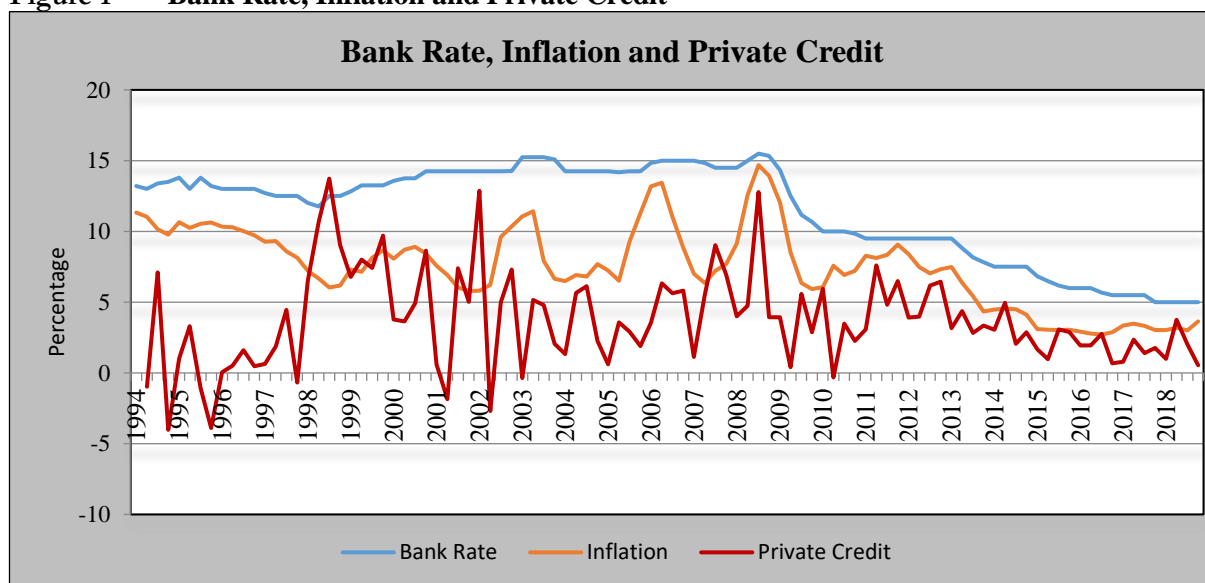
The Bank Rate and BoBCs are also used to influence liquidity constraints in the financial system. During the period of financial repression, the effective demand for credit was limited (Bank of Botswana, 1993). However, during the period of financial liberalisation, mostly from 1997-1999 (see Figure 1), the demand for credit soared.

³ The purpose of the medium-term objective is to support long-term inflation expectations (Bank of Botswana, 2012).

This was attributable to developing competition within the banking industry. This, in turn, resulted in the expansion of specialised and competitive loan schemes (Bank of Botswana, 2000). The resulting surge in demand for credit led to a rise in personal loans to households compared to productive lending (to businesses), as well as a bubble in the housing market. When the bubble burst, consequent challenges with loan servicing became evident. As such, BoBCs were adopted to influence the credit supply and absorb the excess liquidity. Absorbing excess liquidity from the market has also helped to sustain a reduction in inflation⁴ (Bank of Botswana, 2012).

Figure 1 depicts a noticeable spike in private credit in 2008Q3, reflecting increased demand for bank financing associated with an upward income effect on household borrowing during this period. This was encouraged by a wage increase for civil servants and private sector employees in 2008 (Bank of Botswana, 2009). In turn, inflation increased distinctly and peaked in 2008Q3.

Figure 1 Bank Rate, Inflation and Private Credit



Source: Based on data from Bank of Botswana (2019)

Before 1989, exchange rates were used as one of the main monetary policy instruments to curb imported inflation and maintain low inflation rates in Botswana (Setlhare, 2013). Exchange rates have since remained only as a policy variable and a support for

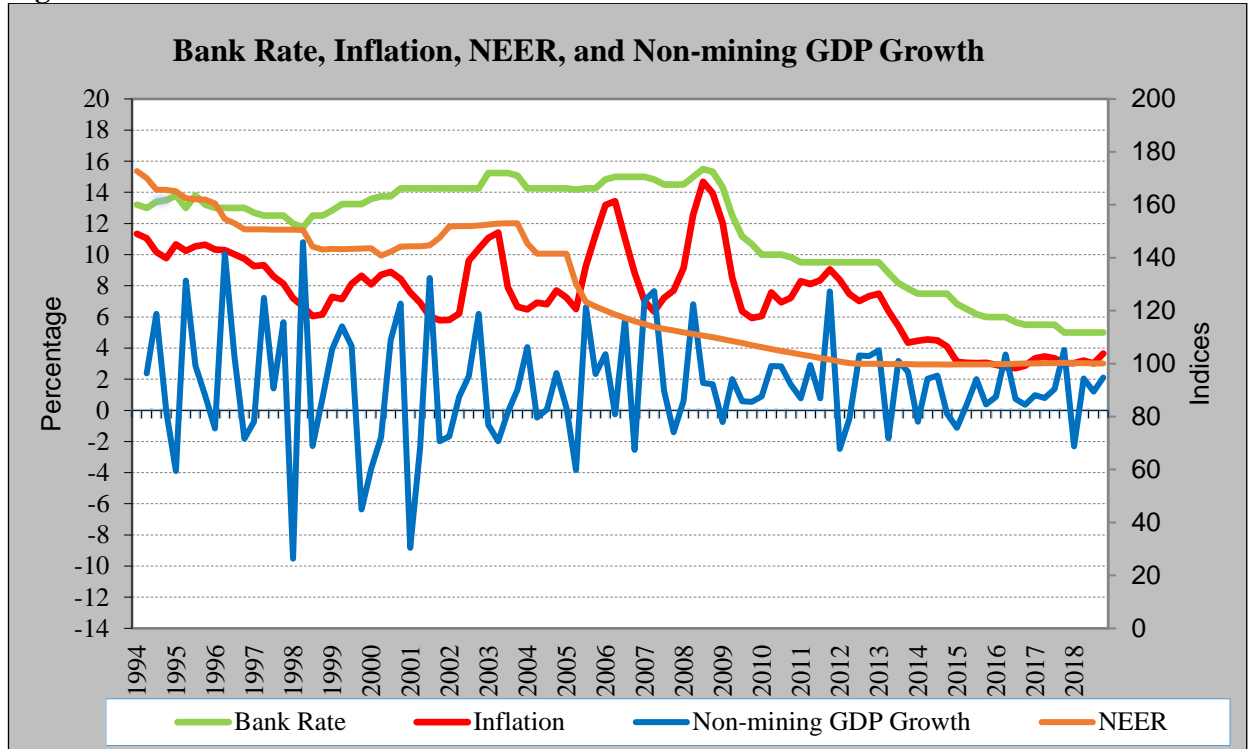
⁴ An excessive credit growth is deemed to cause demand pressures and as a consequence, it may be inflationary.

the monetary policy. The exchange rate regime in Botswana has changed from an adjustable peg to a crawling band mechanism (Mpete, 2015). An adjustable peg regime involved discrete currency devaluations whenever the Bank considered it appropriate. As depicted by Figure 2, there was a noticeable spike of the NEER in 2004Q1, which is attributable to the Pula devaluations of 7.5% in February 2004. In May 2005, Botswana adopted the crawling band exchange rate mechanism⁵ to avoid large discreet adjustments of the nominal effective exchange rate and to preserve a relatively stable real effective exchange rate (REER). The aim was to also enable domestic manufacturers of tradeable goods and services to remain competitive on the international scene. Since the second quarter of 2005, the Pula has continued to crawl downwards (small continuous devaluations), albeit with brief periods of upward crawl, as shown in Figure 2.

Botswana is also pegged to a basket of currencies that reflects the country's trading patterns and comprises 55 percent SDR (the International Monetary Fund's unit of account, composed of US dollar, British pound, euro, Chinese yuan and Japanese yen) and 45 percent Rand. The allocation of basket weights was mainly based on keeping the Pula stable against these currencies. The policy supports export competitiveness, more investment, and growth within a stable macroeconomic environment. This implies that the exchange rate is an essential aspect of Botswana's monetary policy framework, and it may therefore affect the monetary policy transmission mechanism.

⁵ An exchange rate system where the value of domestic currency is adjusted on a regular basis according to a pre-determined formula that takes account of actual or expected inflation differentials (Bank of Botswana, 2012).

Figure 2 Selected Botswana Macro-indicators



Source: Based on data from the Bank of Botswana (2019)

Finally, the main objectives of BoB’s monetary policy are to achieve price stability and sustainable economic growth. Theoretically, monetary policy also affects output through the interest rates, credit and exchange rates channels. Consequently, the time series graphical representation of inflation, the Bank Rate and output⁶ (see Figure 2) showed noticeable spikes in 2009Q1 and 2009Q2, in line with substantial increases in food and oil prices and the 2008/09 recession. Consequently, this caused a sharp drop in non-mining GDP growth.

Policy and structural breaks identified are the motivation to look at the time-varying disposition of the transmission of monetary policy in Botswana. This study, therefore, investigates whether and how macroeconomic and policy changes have affected the transmission of monetary policy over time. The next section discusses the available literature that examines the development of monetary policy transmission over time.

⁶ The study uses non-mining real GDP as a proxy for output. This is because mining is a dominant sector in the economy and has a limited association with the monetary policy framework and other financial institutions, as it is predominantly financed from foreign financial markets. As such, the non-mining real GDP data series is employed to eliminate the possibility of biased results. The study also follows previous analyses of monetary policy transmission in Botswana which employed real non-mining GDP as a proxy for output (for example, Setlhare, 2013).

3 LITERATURE REVIEW

The literature on the effectiveness of monetary policy transmission is widely researched and it encompasses the theoretical and empirical literature. The primary function of this section is to assess how policy and macroeconomic reforms affect monetary policy transmission.

3.1 Theoretical literature

Several theoretical frameworks have been developed to explain the monetary policy transmission mechanism. Examples of such theories include the IS-LM model, the liquidity preference theory, and the McKinnon (1973) financial liberalisation hypothesis. The IS-LM model introduced by Hicks (1973), posits that the transmission of monetary policy occurs through changes in interest rates. The fundamental mechanism here is that monetary policy tightening results in higher interest rates through the demand for transaction balances, which, in turn, affects output (IS curve). When there is an upsurge in interest rates, financing costs also increase, and this would lead to reduced aggregate demand and output. In his liquidity preference theory, Keynes (1936) argues that the amount of capital demanded, which economic agents wish to hold for speculative purposes, is a function of interest rates, as people desire to hold their capital in the form of an interest-bearing asset. As interest rates go up, holding money becomes expensive, resulting in a reduction in the demand for money. It is also important to note that excess aggregate demand may cause inflation in an economy.

The two theories explained above are relevant to the present discussion, but their main weakness is that they ignore the time-varying disposition of the monetary policy transmission mechanism. Nonetheless, the structure of the economy and the relationships between economic variables are complex and change with the passage of time. This section therefore focuses mainly on the McKinnon's (1973) financial liberalisation hypothesis because it best shows the time-varying nature of the transmission of monetary policy by changing the effect of the monetary policy or by altering the transmission mechanism channels.

The McKinnon (1973) financial liberalisation hypothesis provides a good basis for understanding how the financial reforms affect economic activity. The foundation of the hypothesis is that interest rates are positively correlated with a growing economy and that low and negative real interest rates may then hinder growth. On the other hand, financial repression retards growth by causing low interest rates. McKinnon (1973) argues that, in a “repressed” economy, real deposit rates of interest are mostly negative and the interest rates also become extremely uncertain. Shaw (1973) and McKinnon (1973) postulate that this policy lessens the funds available for investment and is therefore detrimental for long-run growth.

The policy and economic reforms, which as discussed in the previous section, are effectively financial liberalisation, are encouraged so that the market can operate more efficiently, and policy decisions by the central banks can be transmitted through the economy most effectively. The financial liberalisation hypothesis posits that financial innovations and deregulation of interest rates cause an upward pressure in real interest rates. This, in turn, leads to growth in investment, savings and efficacy in financial asset distribution. Consequently, increased savings will support a higher level of credit supply. The financial system promotes investment and economic growth, as it makes funds accessible for lending and borrowing (McKinnon, 1973).

The path which monetary policy takes from implementation to outcome is alluded to as the monetary policy transmission mechanism. The various channels through which monetary policy can influence the economy include the interest rate channel, the exchange rate channel, the credit channel and the asset price channel (Mishkin, 1995). These channels elucidate the way monetary policy influences output and inflation. We also show how the policy and economic reforms may affect these channels.

The interest rate channel broadly involves changes in interest rates to influence monetary conditions and, eventually, inflation (Bank of Botswana, 2012). It is expected that a change in the policy rate would affect other short-term market interest rates following the announcement of a change in the policy rate. In addition, a change in the short-term policy rate may also have an impact on consumption, savings, and investment. Nonetheless, these macroeconomic decisions are mainly based on expected real long-term interest rates rather than on short-term nominal interest rates.

Given that prices are sticky in the short run, tighter monetary policy (an increase in the policy interest rate) will lead to an increase in real interest rates, especially if economic agents firmly believe that future inflation will decline. This, in turn, will raise the capital cost. Consequently, the level of consumption and investment will decline, which will ultimately reduce inflation and output (Mies and Tapia, 2003; Smal and De Jager, 2001).

Financial repression or the presence of random limits on interest rate caps would restrict the transmission of interest rate movements. Ceilings would also retard growth by causing low and negative real interest rates, which would result in an unavailability of loanable funds. On the contrary, policy or economic innovations implemented by the Bank of Botswana (which amount to financial liberalisation) as discussed in Section 2, as well as deregulation of interest rates, could possibly result in an upward adjustment in real interest rates. This would lead to increased output through increased savings and investment. When the financial market is well developed and diversified, policy signals will be transmitted more efficiently through to market rates. This is broadly in line with Levine (1997), who argues that improved functional financial systems encourage rapid economic growth. Additionally, the introduction of BoBCs in 1991, which absorb excess liquidity from the market, helps to sustain low levels of inflation.

The exchange rate channel involves the concept of interest rate parity, which describes the relationship between the exchange rate and interest rates in diverse countries. A contractionary monetary policy causes an increase in interest rates, resulting in domestic financial assets being more appealing than assets denominated in foreign currency. This will lead to domestic capital inflows which will cause upward adjustment of the domestic currency. Accordingly, the domestic currency will appreciate as a result of the interest rate parity condition (Mishkin, 1995). The exchange rate appreciation will reduce imported inflation and, ultimately, lead to downward pressures on domestic inflation. Consequently, output will decrease together with inflation.

Before May 2005, Botswana's exchange rate regime was the adjustable peg, which involved large discrete currency devaluations or revaluations each time BoB

considered them essential. To avoid the need for those large discrete changes and to maintain stability within the exchange rate regime, the crawling band was introduced. This is used to keep the Pula from appreciating to levels which may have a negative impact on other sectors of the economy (Mpete, 2015). The nominal effective exchange rate time series (as shown in Section 2) demonstrates Pula devaluations, over most of the study period, which are more distinct after the implementation of the crawling band mechanism in 2005.

The credit channel, on the other hand, emphasises asymmetrical information in financial markets that make it difficult to enforce financial contracts. It is a reinforcing channel used with the interest rate channel. In the credit channel, the transmission is through the bank lending and the balance sheet channels. These channels are used together to explain how a credit shock can affect output and inflation (Kganetsano, 2007).

The bank lending channel is founded on the premise that the banking sector is well equipped to address issues of asymmetrical information in credit markets (Mishkin, 1995). This channel functions through influencing the supply of loanable funds by banks. According to this view, expansionary monetary policy increases bank deposits and reserves, raising funds available for borrowing and thus increasing investment and ultimately output. This allows banking institutions to increase lending and investment to rise.

The balance sheet channel assumes that the financial position of a borrower influences the interest rate they are charged. A borrower who has available resources that can be used as collateral is charged a lower rate. Therefore, this channel assumes that any change in the borrower's financial position is highly likely to affect the quality of the borrower's balance sheet, and, in turn, his or her spending and investment decisions. For instance, a tight monetary policy action results in high interest rates, leading to a high cost of borrowing. This will then dampen gross fixed capital formation and demand and inflation will decrease as a consequence (Bernanke and Gertler, 1995).

Under financial repression, credit is not readily available on demand because of very low interest rates. Theoretically, credit stimulates output. However, excess liquidity

may be inflationary and, as a result, have deleterious effects on the economy. Financial liberalisation, which resulted in the emergence of competition in the financial and banking sectors, brought about increased liquidity in the economy. BoB therefore introduced BoBCs and relaxed foreign exchange controls in 1991 in an effort to mop up the surplus liquidity and channel the liquidity into productive investments to induce output.

Given Botswana's relatively less developed financial system, particularly the stock market, and a lack of long-series and good quality data in Botswana, the asset price channel will not be considered in this study. The monetary policy transmission channels discussed differ in various countries owing to the development levels of their respective financial markets and macroeconomic conditions (Dabla-Norris and Floerkemeier, 2006). It is imperative to remember that when policy changes, the effect on parameters and therefore, on the monetary transmission, may change as well.

Consistent with the above theoretical review, particularly the financial liberalisation theory, macroeconomic elements (which are also monetary policy variables) influence economic activity over time. These factors include, amongst others: interest rates, credit to the private sector, inflation, investment, and savings. The theoretical model can be specified in a functional form as:

$$GDP=f (int_t, cpi_t, pc_t, inv_t, sav_t) \dots\dots\dots (i)$$

Where GDP, int, cpi, pc, inv, sav denote, respectively, real GDP, interest rates, consumer price index as a proxy for domestic inflation, credit supply to the private sector, investment and savings.

The discussion which follows focuses on the empirical findings which unveil how policy reforms affect the monetary policy transmission, and ultimately economic activity over time.

3.2 Empirical literature

Numerous studies have analysed the transmission mechanisms of monetary policy. However, the results are inconclusive because some studies assume that there is a

single regime and therefore parameters do not change or are time invariant. However, in reality, when policy changes and there are structural changes in the economy, the effect on parameters may change as well. This is a gap that this study attempts to fill. The inconclusive results could also reflect the differing transmission channels between developing and developed economies (Holtemöller, 2003). This disparity may be due to the development levels of their respective financial markets and macroeconomic conditions as highlighted above.

There is a well-established empirical literature for developed countries on the monetary transmission mechanism, for instance, Amarasekara (2008), Bredin and O'Reilly (2004), and Peersman and Smets (2001). These studies mostly base their analysis on single-regime models and assume parameters do not change over time. They use the recursive VAR and structural VAR models in their studies, following the influential work of Sims (1980). The common variables used in these studies include interest rates, prices, GDP, exchange rates, and money aggregates. Results found in these papers support established economic theory and empirical evidence. Generally, these studies observe that a positive shock in the interest rate leads to a decline in GDP and inflation, and a depreciation in the exchange rate. While the basis of these results may be less precise due to unrealistic time-invariant coefficients, the results generally show that the channels of transmission mechanisms are mostly functional. This supports Mishra and Montiel's (2012) findings that developed countries are characterised by well-functioning and robust financial markets, making the monetary transmission mechanism effective.

In developing countries, the effectiveness of monetary policy transmission has also been a topic of empirical interest. The majority of studies, for example, Dabla-Norris and Floerkemeier (2006) and Ngalawa and Viega (2011) have used models that assume constant parameters. Both studies, using VAR frameworks and common variables which include prices, interest rates, GDP, money supply and exchange rates, find that monetary policy has the capacity to affect economic activity and inflation, notwithstanding its limited effect. Moreover, these studies reveal the issue of price puzzle, consistent with Primiceri (2005), who argues that studies which assume time-invariant parameters may find it difficult to establish evidence of the impact of

monetary policy innovations on output and domestic prices, as well as encounter issues of price puzzles.

These results, as argued by Mishra and Montiel (2012), could also be due to the absence of well-functioning and robust financial markets and heavy central bank involvement in foreign exchange markets in most less-developed countries. Lastly, poor quality data and the lack of a long series, as identified in some of these studies, may be the underpinning reason for the results found. Alternative approaches, such as factor-augmented vector autoregressive (FAVAR) methodology, Bayesian vector autoregressive and TVP-VAR could be used as they circumvent the problem of poor-quality data and short-series data.

In investigating the monetary policy transmission in Gulf Cooperation Council (GCC) countries, Prasad and Espinoza (2012) use GDP, CPI inflation, money aggregates, government expenditure and policy rates variables based on cointegration and panel-vector analysis. A panel vector regression model shows that U.S monetary policy has a significant impact on non-oil activity, broad money and inflation in the GCC region. Ma and Lin (2016) also examine the relationship between financial development and the effectiveness of monetary policy based on panel-data analysis from 41 economies. Variables used include money growth rate, output, the inflation rate and credit. They conclude that the impact of monetary policy on output and inflation correlate, significantly and negatively, with financial advancement. This result contradicts the established theory that the efficiency of monetary policy is likely to become positive as the financial market gets highly advanced. The weakness of these panel studies is that the findings are mostly generalised. This makes it challenging to formulate country-specific policies to address the problem at hand because of differences in institutional and economic activities. It is therefore imperative to assess a single country in order to draw relevant policies for that country.

The weakness of the reviewed literature is that the relationships among variables are time invariant. The studies fail to assess how shocks hitting the economy, and how changes in the way variables respond to shocks, evolve over time. This may cause a misinterpretation of the transmission of monetary policy. The structure and the relationship between economic variables change over time, therefore a regime-

switching or time-varying analysis allows a better understanding of how changes in policy affect the economy, particularly the monetary policy transmission mechanism.

Primiceri (2005) and Nakajima, Kasuya and Watanabe (2011) argue that the overall effectiveness of monetary policy is simply influenced by changes in the structure of the economy through altering the monetary transmission mechanisms. They study the time-varying nature of monetary policy in the American and Japanese economies, respectively, using the Bayesian analysis for the TVP-VAR. These studies improve and complement the existing literature by taking into consideration structural breaks and thus the time-varying nature of parameters. Using common variables identified in the theoretical literature which include inflation rate, unemployment rate, industrial production and nominal interest rate, both studies find proof of time variation in their respective economies' monetary policy. In addition, these papers do not find the issue of price puzzle that has been found in most studies that use single-regime models with time-invariant or constant parameters.

In order to understand better, the implications of policy innovations, Korobilis (2013) and Liu, Song and Huang (2019) evaluate the transmission of monetary policy for the American and Chinese economies, respectively. They employ the time-varying factor augmented VAR (TVP-FAVAR) model. The results found by Liu, Song and Huang (2019) affirm the traits of time-varying effects. They find that the price rule is more efficient than the quantity rule, supporting the authorities' policy of liberalising interest rates. The authors also find that central-bank changes in Chinese interest rates have considerable effects on inflation. Korobilis (2013), using monetary aggregates, output, prices, interest rates, investment, and employment in the model, shows that notable changes occurred in the impulse responses of investment, output, and the quantity of money to monetary shocks over the three respective periods used.

Notably, the above studies contributed significantly to previous literature in that the TVP-FAVAR model generates impulse responses of inflation which minimise the problem of price puzzle, making the results of the study more reliable. Furthermore, Lange (2010) investigates Canada's monetary policy and takes into consideration policy and structural changes by using a regime switching model. The author also allows for contemporaneous policy reactions to financial disturbance in an open

economy. The main conclusion is that monetary policy in Canada has experienced significant monetary regime changes since the 1970s that are in line with amendments in operational measures and inflation objectives (Lange, 2010).

In Africa, Mwabutwa, Bittencourt and Viegi (2013) and Owusu-Sekyere (2017) assess the monetary policy transmission mechanism in Malawi and South Africa, respectively. These studies allow for coefficients to vary by employing a TVP-VAR Approach. Mwabutwa et al. (2013) corroborate that the transmission mechanism of Malawi did experience outstanding changes following financial reforms. Their study reveals that output, exchange rate and CPI reactions to monetary policy shocks changed over the period under study. No evidence of price puzzle was found in Malawi. In South Africa, Owusu-Sekyere (2017) evaluated the effect of monetary policy on household consumption, and found that credit to households and consumption decreased and remained negative after inflation targeting, but increased during the 2009 economic crisis owing to an expansionary monetary policy. The results reflect the effect of different structural changes on South Africa's monetary policy conduct. However, the study only focuses on one sector of the economy and does not give a holistic view of the transmission channel on macroeconomic variables.

Lastly, previous work on Botswana's monetary policy transmission (Kganetsano, 2007 and Setlhare, 2013) has focused only on time-invariant relations among variables. This is in spite of a background of structural and policy changes in the economy and the monetary framework. Kganetsano (2007) estimated the monetary policy transmission channels in Botswana. The author estimates a VAR model using output, inflation, money supply and policy rate, and finds that, consistent with the literature, output decreases in response to increases in the interest rate. Kganetsano (2007) also found the price puzzle issue. Setlhare (2013) used a recursive SVAR model, which was ordered as South African Treasury bill rate, non-mining GDP, inflation, Bank Rate and the nominal and real effective exchange rates. The author finds that monetary policy is weakly transmitted to inflation through both the interest rate and exchange rate variables. The model also generates a price puzzle. In addition, Setlhare (2013) estimates sub-samples, as opposed to allowing the regimes to switch within the model. This cuts down on the data in a way that is likely to influence the results.

The results for Botswana are similar to reviews of other developing countries which did not include the time-varying aspect. This broadly resulted in finding limited impact of monetary policy on both output and inflation, as well as the issue of price puzzle. This could be attributed to the fact that when policy changes or there are structural changes in the economy, the effect on parameters may change as well, an aspect that was ignored by these studies. This is the gap that this study fills. Following the significant structural reforms to the economy and monetary framework discussed in Section 2, a method that allows for the variation of parameters over time in Botswana may provide information on how the monetary mechanism has evolved. Empirical results could differ from those of the previous two studies that did not allow for this time-varying effect.

Several methods have been used in the literature to analyse the transmission of monetary policy. These methods include panel data regressions, FAVAR approaches, VAR and structural VAR methods and the TVP-VAR model, etc. Panel data regressions can be criticised given that they require homogeneity and coefficients may differ between specific countries. Thus, the results obtained from panel regressions represent a relationship which is generalised and may not be applicable to specific countries (Keho, 2011). This is because the literature has proved that monetary policy transmission mechanisms differ across countries. Panel data methods would therefore not be suitable for the case study of Botswana.

VARS are particularly beneficial for impulse-response studies, while SVAR allows for the identification of specific independent shocks that are not affected by covariance terms. However, economic interpretation of results may be impeded by the lack of “structure” in VAR models. This may also be because standard VARS are time-invariant and, therefore, fail to obtain the probable heteroscedasticity of shocks and nonlinearities in the simultaneous connections between the variables in the model (Primiceri, 2005). Another disadvantage of the standard VAR model is that it is highly parametrised, which implies that degrees of freedom problems could be encountered when including several variables or many lags. This could cause distortions in the impulse responses and measurement errors (Blanchard and Fischer, 1989). All these suggest that traditional VAR models may be prone to instabilities.

A few estimation or forecasting methods may be used to improve the accuracy of forecasts from a VAR and SVAR, such as using time-varying parameters or model averaging. Tsangarides (2010) points out that while many different structural factors could lead to instabilities in macroeconomic variables, structural breaks are regarded as the primary cause of poor performance. Clark and McCracken (2008) argue that when the VAR is estimated with time varying parameters using the Bayesian method or using modelling averaging, the forecast consistency performs amongst the best methods. The FAVAR methodology is also superior to most methods, as it is used to circumvent the problem of poor-quality data and short-series data. However, the FAVAR approach is also time invariant.

Adopting the TVP-VAR method is more beneficial as it provides a more useful tool for assessing the transmission mechanism and the impact of monetary policy, particularly in conditions where there are significant structural changes and data problems (particularly short-series data). The TVP-VAR model is appropriate for this study and its use is informative following the significant structural changes in Botswana's monetary policy framework, as well as prevalent global financial developments over the sample period. These structural reforms could alter the overall monetary policy impact.

This study fills a gap in the existing literature on Botswana by allowing both the coefficients and the variance of the structural shocks to change over time. We consider the time-varying nature of parameters with the intention to reveal how changes in policy have affected the monetary policy transmission mechanism. Reviewed literature has revealed an absence of studies on monetary policy that consider the time-varying nature of parameters in Botswana in particular. The TVP-VAR model is employed to analyse how structural and policy changes influence the monetary policy transmission mechanism over time. Specifically, the study uses real non-mining GDP, consumer price index, credit to the private sector, the Bank Rate and the nominal effective exchange rate to investigate the subject matter. The next section reviews this dynamic method and the data.

4 DATA AND METHOD

The study seeks to analyse the time-varying characteristics of monetary policy transmission in Botswana, as reviewed in the previous section. Therefore, this section, provides a discussion of the data and analysis process. In addition, the choice of variables, the model specification, Bayesian inference, variable ordering and selection of priors are presented.

4.1 Data

This study uses quarterly time series data for the period 1994Q1- 2018Q4. The choice of the sample period is based on the data availability from various sources. The variables considered are the Bank Rate (BR), real non-mining domestic output, measured as the value of constant price non-mining GDP at 2006 prices (NMGDP), the consumer price index (CPI), credit to the private sector (PC), and the nominal effective exchange rate (NEER). The data used in this study were sourced from Bank of Botswana and Statistics Botswana. Quarterly NMGDP data is used; CPI, PC, BR and NEER were converted into a quarterly series by calculating three-month averages. We take the natural logarithms of output, the consumer price index, the exchange rate and credit to the private sector in order to improve the model fit by compressing the scale in which the variables are measured, thereby reducing variation. The analysis used Microsoft Excel 2016, E-views 11 and OX software.

4.2 Choice of variables

In this study, the consumer price index (CPI) is employed as a proxy for domestic prices. This is an appropriate proxy as approximately 70 percent of tradeable commodities are contained in the Botswana's CPI basket. Some studies (e.g., Primiceri, 2005 and Korobolis, 2013) use industrial production as a proxy for GDP, but this data is not available in Botswana. Real non-mining GDP (NMGDP) is used as a proxy for economic output. This is because it is a good and common proxy for economic activity. The central bank policy rate, referred to as the "Bank Rate", is also used to depict monetary policy shocks. The Bank Rate serves to measure the short-term interest rates. The Bank of Botswana uses the policy interest rate mostly to moderate inflationary pressures in the economy (Bank of Botswana, 2012).

Since Botswana is an open country and the Pula is pegged to a basket of currencies, Botswana is highly likely to be affected by external factors. Therefore, the nominal effective exchange rate (NEER) is used, given that it is a trade-weighted average of a basket of currencies of the country's major trading partners. The effective exchange rate index represents the actual extent of the exchange rate fluctuations within the economy (Bank of Botswana, 2009). The NEER is therefore an important aspect of Botswana's monetary policy framework and could have ramifications for the monetary policy transmission mechanism, as discussed in the theoretical literature. An exchange rate appreciation (depreciation) is measured as an increase (decrease) in the foreign currency per unit of the domestic currency. To explore the credit channel, we include private credit supply. Credit supply is credit from commercial banks to the private sector in Botswana.

4.3 Model specification

The economic model for this study has been specified following Nakajima (2011), Nakajima and Watanabe (2011) and Primiceri (2005), who use a Bayesian TVP-VAR model that allows parameters to vary over time. The model has a state-space form⁷ and the measurement equation is specified as follows:

$$\mathbf{y}_t = \mathbf{c}_t + \mathbf{B}_{1,t}\mathbf{y}_{t-1} + \dots + \mathbf{B}_{s,t}\mathbf{y}_{t-s} + \boldsymbol{\mu}_t, \quad t = s + 1, \dots, n, \quad \boldsymbol{\mu}_t \sim \mathbf{N}(\mathbf{0}, \boldsymbol{\Omega}_t) \quad (1)$$

From equation (1), \mathbf{y}_t is a $k \times 1$ vector of observed variables, \mathbf{c}_t is a $k \times 1$ vector including time-varying intercept terms, and $\mathbf{B}_{1,t}, \dots, \mathbf{B}_{s,t}$ are $k \times k$ matrices of time varying coefficients. The error term $\boldsymbol{\mu}_t$ is a vector of unobservable structural shocks that follows normal distribution with a zero mean and a $k \times k$ time-varying variance-covariance matrix $\boldsymbol{\Omega}_t$. The time-varying covariance matrix reflects both time variation of the simultaneous relations among the variables of the model and possible heteroscedasticity of the innovations. The variance-covariance matrix assumes a recursive identification and is re-written using a triangular reduction as follows:

$$\boldsymbol{\Omega}_t = \mathbf{A}^{-1} \boldsymbol{\Sigma}_t \boldsymbol{\Sigma}_t' (\mathbf{A}_t^{-1})' \quad (2)$$

⁷ State space models deal with dynamic time series problems that involve unobserved variables or parameters that describe the evolution in the state of the underlying system. They are particularly useful when dealing with dynamic time series, as well as models for TVP.

Where A_t is a lower triangular matrix reflecting the simultaneous relationships among the variables with the main diagonal elements all equal to one. Furthermore, the matrix A_t is allowed to vary over time. Σ_t is a diagonal matrix for idiosyncratic shocks:

$$A_t = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1,t} & \cdots & a_{k,k-1,t} & 1 \end{pmatrix}$$

$$\Sigma_t = \begin{pmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \cdots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{k,t} \end{pmatrix}$$

Equation (1) can be re-specified as the following reduced form VAR model. This is done in order to circumvent having a contemporaneous effect between the variables concerned. However, shocks will still have contemporaneous effects.

$$\mathbf{y}_t = \mathbf{c}_t + \mathbf{B}_{1,t}\mathbf{y}_{t-1} + \cdots + \mathbf{B}_{s,t}\mathbf{y}_{t-s} + \mathbf{A}^{-1}\Sigma_t\boldsymbol{\epsilon}_t, \quad \boldsymbol{\epsilon}_t \sim N(\mathbf{0}, \mathbf{I}_n) \quad (3)$$

B_t is defined as a stacked row of B_1, \dots, B_k to attain a reduced form depiction which can be written as follows:

$$\mathbf{y}_t = \mathbf{X}_t\mathbf{B}_t + \mathbf{A}^{-1}\Sigma_t\boldsymbol{\epsilon}_t \quad (4)$$

$$\mathbf{X}_t = \mathbf{I}_n \otimes (1, \mathbf{y}'_{t-1}, \dots, \mathbf{y}'_{t-s}),$$

\otimes denotes the Kronecker product. Meanwhile, following Primiceri (2005), $\mathbf{a}_t = (a_{21}, a_{31}, a_{32}, a_{41} + \dots + a_{k,k-1})'$ is a stacked vector of the lower-triangular elements of matrix A_t . It is assumed that B_t , A_t and Σ_t all change over time. Furthermore, it is presumed that the log-volatility measured by the log of variances is $\mathbf{h}_t = (h_{1t}, \dots, h_{kt})'$, $h_{jt} = \log \sigma_{jt}^2$ for $j = 1, \dots, k$, $t = s + 1, \dots, n$, and it is also modelled to follow a random walk.

As discussed by Primiceri (2005), equation (4) is re-specified as a state-space model by stipulating the evolution of time-varying parameters founded on the following equations:

$$\begin{aligned}
B_t &= B_{t-1} + V_t \\
\alpha_t &= \alpha_{t-1} + \xi_t \\
h_t &= h_{t-1} + \eta_t
\end{aligned}
\quad
\begin{bmatrix} \varepsilon_t \\ V_t \\ \xi_t \\ \eta_t \end{bmatrix} \sim N \left[0, \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{bmatrix} \right]$$

For $t = s + 1, \dots, n$.

Where:

$$\beta_{s+1} \sim N(V_{\beta 0}, \Sigma_{\beta 0}), \alpha_{s+1} \sim N(V_{\alpha 0}, \Sigma_{\alpha 0}), h_{s+1} \sim N(V_{h 0}, \Sigma_{h 0})$$

I_n is an n -dimensional identity matrix. The time-varying parameters B_t and α_t , follow a random walk process as indicated by the first two transition equations. The random-walk assumption can capture possible gradual or sudden structural change of the underlying economic structure in stochastic volatility (Primiceri, 2005). In contrast, the third equation indicates that the vector of stochastic volatilities reflects an independent random walk. The shocks to the innovations $(\varepsilon_t, V_t, \xi_t, \eta_t)$ of the time-varying parameters are presumed to be jointly normal and uncorrelated among the time-varying parameters, suggesting that the parameters of the matrix vary independently in each equation.

4.4 Bayesian inference

TVP-VAR involves estimating several parameters, and thus increases the chances of over-parametisation, which deters accurate measurement of the parameters and impulse responses (Koop and Korobilis, 2010). Subsequently, the TVP-VAR is estimated using the Markov Chain Monte Carlo (MCMC) methods in the context of a Bayesian inference. The following factors make Bayesian methods particularly suitable for estimating this class of models (state-space models). “Bayesian methods are used to evaluate the joint posterior distributions of the parameters of interest, i.e., the unobservable states and the hyperparameters of the variance covariance matrix V , based on set prior probabilities densities” (Primiceri, 2005:826). Moreover, MCMC deals efficiently with issues of high dimensionality of the parameter space and preserves parsimony in estimating the time-varying parameters. This approach also deals with issues of non-linearities of the model (introduced by the time-varying nature of the parameters) by splitting the original estimation problem into smaller and simpler ones, resulting in smoothed estimates (Primiceri, 2005).

4.5 Selection of priors

The same priors as the ones in Nakajima (2011) for Japan are employed. Nakajima's (2011) priors are also used in two South African studies (Mwabutwa, Bittencourt and Viegi, 2013; Owusu-Sekyere, 2017). Japan and South Africa are both, like Botswana, small, open economies. This justifies the use of these priors. Moreover, South Africa and Botswana have other similarities; for example, they are both commodity exporters. Therefore, these priors are most suitable for this study and are also convenient in their application. The priors are specified as:

$\Sigma_t \sim IW(25, 0.01I)$, $(\Sigma_a)_i^{-2} \sim Gamma(4, 0.02)$ and $(\Sigma_h)_i^{-2} \sim Gamma(4, 0.02)$ where IW signifies the invert Wishart distribution, $(\Sigma_a)_i^{-2}$ and $(\Sigma_h)_i^{-2}$ represent the $i = th$ diagonal elements of the matrices. Lastly, for the initial set of the time-varying parameters, we use the flat priors such that $\mu_{\beta_0} = \mu_{a_0} = \mu_{h_0} = 0$ and $\Sigma_{\beta_0} = \Sigma_{a_0} = \Sigma_{h_0} = 10 \times I$.

4.6 Ordering of Variables

The ordering of variables ought to be in line with economic theory (Bernanke, 1990). The ordering starts with variables that are most exogenous, these being external shocks to the economy, while the most endogenous are ordered last (Bernanke, 1990). For this study, we estimate two models. The variables for the first model, which explore the interest rate and exchange rate channels, are ordered as (NMGDP, CPI, BR, NEER). This recursive ordering is theoretically intuitive in that real output and prices are unlikely to react immediately to the Bank Rate (Bernanke, 1990; Höppner, Melzer and Neumann, 2008). The changes in the Bank Rate will only affect real NMGDP and CPI with a lag. Setlhare (2013) also employed this ordering in a study of the monetary transmission mechanism in Botswana. In the second model, the NEER is replaced with credit to the private sector in order to explore the credit channel. Theoretically, an increase in the monetary policy interest rate results in a surge in the cost of credit (Mies and Tapia, 2003). This in turn, is anticipated to decrease investment and consumption, causing a reduction in credit, GDP and inflation. As such, the variables in this model are ordered as (NMGDP, CPI, PC, BR). This ordering was also used by Mwabutwa et al. (2013).

5 EMPIRICAL RESULTS

This section discusses the analysis of the findings and their relevance to the available literature and sets a base for the conclusion on the declared research objective.

5.1 Descriptive Statistics

Table A 1 (see appendix) shows the summary statistics for all variables. In order to deal with skewness towards large values in the data, all variables, except the Bank Rate, are transformed using logs. The various descriptive statistics examined include the mean, median, maximum, standard deviation, skewness, kurtosis, Jarque-Berra, probability, sum squared deviation and number of observations. The descriptive statistics show that three variables are negatively skewed, while two are positively skewed, but all with a value of skewness near zero. This implies that our data have approximate normal distribution. In addition, the kurtosis values are less than three, reflecting that the data are platykurtic. Using the Jarque-Berra test, we fail to reject the null hypothesis of normality for all variables and conclude that the data are normally distributed with a mean of zero and constant variance.

According to Table A 2, the Bank Rate is negatively correlated with non-mining GDP, CPI, and private credit. In contrast, the nominal effective exchange rate shows a positive relationship. The NEER is also found to be negatively correlated to non-mining output, CPI and private credit. Lastly, there is an expected positive relationship between private credit and output, and between private credit and CPI. This is because according to economic theory, while private credit may induce economic growth, excessive private credit is inflationary. Therefore, we would expect a positive relationship between private credit and CPI and output.

To test for multicollinearity, the Variance Inflation Factor (VIF) test is conducted and the results are presented in Table A3. The coefficient variance is less than 10 for all variables, which indicates that the null hypothesis of no multicollinearity cannot be rejected.

5.2 Unit root tests

Estimating empirical models using time series data necessitates that the variables used be stationary. This is because a stationary variable has a time-invariant mean and covariance; and hence estimation based on non-stationary variables may lead to spurious results. This implies that unit root tests ought to be conducted before carrying out analysis to find the order of integration. In this regard, we apply the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to find the order of integration of the variables as shown in Table 1. However, both these tests tend to be inclined towards the non-rejection of the unit root in the presence of structural breaks. As there are structural breaks in the data,⁸ the Zivot and Andrews (1992) unit root test is also used, which is particularly beneficial when there is a possibility of an unknown endogenous structural break.

Table 1 ADF and PP Unit Root Tests

Variables	ADF		PP	
	Level	Differenced	Level	Differenced
Private Credit (PC)	0.8814	0.0000*	0.8935	0.0000*
Non-mining Real Output (NMGDP)	0.7512	0.0000*	0.6597	0.0001*
CPI	1.0000	0.0000*	1.0000	0.0000*
Bank Rate (BR)	0.9726	0.0000*	0.9826	0.0000*
Exchange rate (NEER)	0.6576	0.0000*	0.6109	0.0000*

Note: * and ** represent rejection of the null hypothesis at 1% and 5% level of significance, respectively. Test equations include individual intercept and trend (NMGDP, PC and CPI) and intercept only for the variables without a trend (NEER and BR). The null hypothesis is the presence of unit root (non-stationary) and the alternative is stationarity.

⁸ The Quandt tests and Chow tests (see appendix) indicate the presence of a structural break in the series.

Table 2 Zivot-Andrews Unit Root Test

Variables	Levels			1 st Difference		
	<i>t</i> -statistic	TB	outcome	<i>t</i> -statistic	TB	outcome
Private Credit (PC)	-2.7300	2014	Unit root	-4.8572**	2016	Stationary
Non-mining Real Output (NMGDP)	-4.1307	2015	Unit root	-9.9392*	2015	Stationary
CPI	-2.3862	2016	Unit root	-7.8469*	2000	Stationary
Bank Rate (BR)	-6.7570*	2008	Stationary			
Exchange rate (NEER)	-0.9637	1997	Unit root	-6.0522*	2005	Stationary

Note: * and ** represent rejection of the null hypothesis at 1% level and 5% level of significance, respectively. Test equations include individual intercept and trend (NMGDP, PC, and CPI) and intercept only for the variables without a trend (NEER and BR). TB denotes potential break-date.

When using the ADF and PP tests (Table 1), the results of the unit root test indicate that all variables are integrated of order 1. Similarly, the Zivot and Andrews (1992) structural break unit root test, which is performed because of the presence of structural breaks in our data series, indicates that all variables achieve stationarity at first difference, as shown in Table 2, except for the Bank Rate which is $I(0)$. Our specification is based on the Zivot-Andrews test given the reasons already provided.

5.3 Cointegration tests

A necessary but not sufficient requirement for the Johansen cointegration test is that each of the variables should be integrated of the same order. It is therefore important to estimate any relationship between these variables in first difference, to avoid spurious results. The Zivot and Andrews test indicates that there is no cointegration because variables are integrated of both order 1 and 0. However, because the PP and ADF tests indicate that all the variables of interest become stationary after the first difference, we still test for cointegration.

A cointegration test was conducted to establish whether there may be co-movements of these variables, and the possibilities of them trending together towards a long-run equilibrium-state. Using the Johansen cointegration test (Table 3), the trace statistic and the maximum-eigenvalue statistic both indicate the non-existence of cointegrating vectors at the 5% level of significance. Thus, the null hypothesis of no cointegration relationship cannot be rejected since the computed values are lower than their respective critical values. For the model with credit (Table 4), the trace statistic

indicates that there is at most one cointegrating vector. The maximum-eigenvalue statistic on the other hand, indicates the non-existence of cointegrating vectors at the 5% level of significance, thus, we fail to reject the null hypothesis of no cointegration relationship. Applying the Johansen test using the maximum-eigenvalue statistics confirms the absence of a long-run relationship among the variables. The maximum-eigenvalue statistics was chosen over the trace statistics results for this model based on the TVP-VAR theory that postulates that the shocks of innovations of the time-varying parameters are assumed to be jointly normal and uncorrelated among the parameters (Primiceri, 2005). Moreover, other studies that used the TVP-VAR model did not consider cointegration (Nakajima, 2011; Mwabutwa et al., 2013; Liu et al., 2019). Lastly, the maximum-eigenvalue statistics reinforces that the Zivot-Andrews unit root test is more accurate than the ADF and the PP tests.

Table 3 Johansen Cointegration test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.196799	51.31203	63.87610	0.3574
At most 1	0.157059	30.27358	42.91525	0.4861
At most 2	0.090257	13.87121	25.87211	0.6682
At most 3	0.048674	4.790221	12.51798	0.6267

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.196799	21.03845	32.11832	0.5693
At most 1	0.157059	16.40237	25.82321	0.5091
At most 2	0.090257	9.080991	19.38704	0.7161
At most 3	0.048674	4.790221	12.51798	0.6267

Trace test indicates 0 cointegrating eqn(s) at the 0.05 level

Max-eigenvalue test indicates 0 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values.

Table 4 Johansen Cointegration test (for the model that includes credit)**Unrestricted Cointegration Rank Test (Trace)**

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.262593	66.55546	63.87610	0.0293
At most 1	0.200729	37.31233	42.91525	0.1624
At most 2	0.127256	15.80300	25.87211	0.5084
At most 3	0.028100	2.736182	12.51798	0.9063

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.262593	29.24312	32.11832	0.1079
At most 1	0.200729	21.50933	25.82321	0.1678
At most 2	0.127256	13.06682	19.38704	0.3227
At most 3	0.028100	2.736182	12.51798	0.9063

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Max-eigenvalue test indicates 0 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values.

5.4 Lag determination

The results of the tests used in determining the suitable lag length are presented in Tables A8 and A9 in the appendix. These tests, which include the Akaike information criterion (AIC), the sequential modified LR test and the Schwarz information criterion (SC), provide information about the number of lags that should be included in the VAR model. Lag length determination is normally determined by AIC and SC lag order selection criteria. They are preferred because they perform better as they impose a penalty if many regressors are included. An optimal lag length of two lags is applied to a TVP-VAR and constant-parameter VAR model. Two lags were also chosen for both models (in Tables A8 and A9 of the Appendix) based on the majority of the lag selection criteria, which included the AIC.

We now discuss the impulse responses to the Bank Rate, exchange rate shocks and effects of credit shocks. The results of the TVP-VAR with stochastic volatility are

compared with the standard VAR model. In the first model, the interest rate and exchange rate channels include four variables, namely: real non-mining output (NMGDP), prices (CPI), the nominal effective exchange rate (NEER), and the Bank Rate (BR). The NEER was replaced in the second model with credit to the private sector (PC) to explore the credit mechanism channel.

5.5 Posterior Estimates for Stochastic Volatility of the Structural Shocks and Simultaneous Relationship

The TVP-VAR estimates for the first set of variables (real non-mining GDP, consumer price index, Bank Rate, nominal effective exchange rate) are presented in Table 5. The table shows outcomes for the posterior means, posterior standard deviation, 95% credible intervals, the Geweke convergence diagnostics (CD) and the inefficiency factors, which are estimated using MCMC sample (Nakajima, 2011).

The results indicate that all Geweke CD values are less than unity, implying that the null hypothesis of convergence to the posterior distribution cannot be rejected. Table 5 also suggests an efficient sampling of posterior draws as the inefficient factors are below 100. This implies that the sum of iterations is adequate for the convergence of the parameters of the TVP-VAR model. Furthermore, the estimated posterior mean for each parameter falls within their respective 95% credible intervals. This implies that the estimated posterior means are close to the true value of the parameters and, in turn, shows that the MCMC algorithm generates efficient posterior draws.

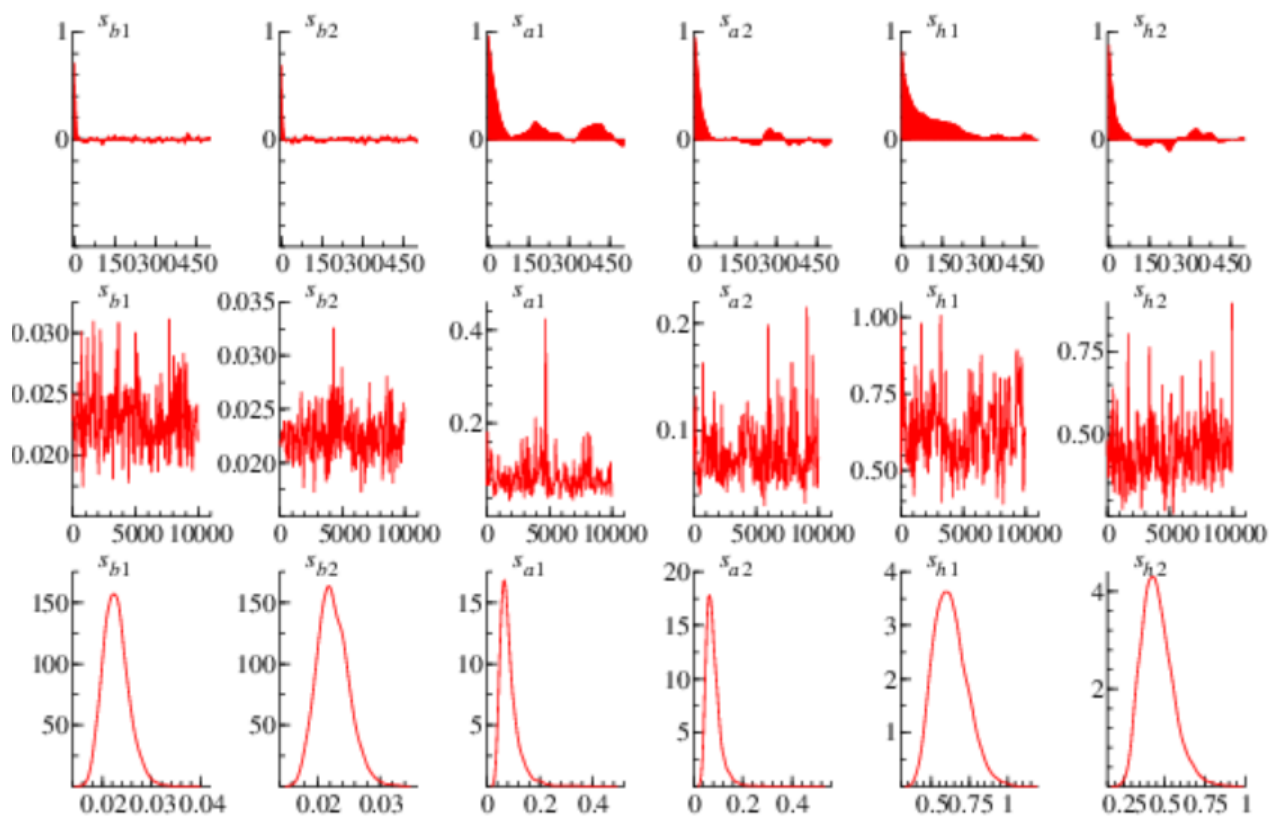
Table 5 Estimation of Selected Parameters in the TVP-VAR Model

Parameter	Mean	Stdev	95%L	95%U	Geweke	Inef.
sb1	0.0227	0.0027	0.0183	0.0287	0.396	8.04
sb2	0.0225	0.0025	0.0183	0.0279	0.138	4.06
sa1	0.0816	0.0340	0.0426	0.1719	0.619	47.01
sa2	0.0999	0.0507	0.0437	0.2338	0.624	48.35
sh1	0.6233	0.0973	0.4619	0.8469	0.400	98.51
sh2	0.4696	0.0883	0.3228	0.6655	0.198	33.52

Figure 3 displays, respectively, the sample autocorrelation, sample paths, and densities of the parameters for the first model. Autocorrelations in the first row of every figure

all drop steadily and range somewhat close to the 0-level indicating that the sample path is quite steady. As argued by Primiceri (2005), this suggests that the sampling technique generates samples with negligible autocorrelation. Additionally, the sample paths in the subsequent panel were all relatively stable, suggesting that the samples resulting from the MCMC method were efficient (Nakajima et. al., 2011). Lastly, the posterior densities in the third panel suggest that the MCMC estimations lead to stable samples.

Figure 3 Sample Autocorrelation, Sample Paths and Posterior Densities for Selected Parameters



Note: The Figure shows sample autocorrelations (top), sample paths (middle) and posterior densities (bottom).

Impulse responses provide the responsiveness of the dependent variable to a unit shock and map out how the effect dissipates over time. A positive shock to the variables represents an increase in these variables. In each graph of the standard VAR model, the solid line is the estimated response, whereas the dashed line denotes the two standard error bands around the estimate.

The impulse responses for the standard VAR model for Botswana (Figure 4) indicate that a one standard deviation positive shock in the Bank Rate leads to a negative response of output, albeit by a small magnitude. This result is theoretically intuitive. Nonetheless, the response of real non-mining GDP to the Bank Rate shock is statistically insignificant throughout the focus horizon.

We find a positive instantaneous response of prices to the Bank Rate, albeit not significantly, since the zero line lies inside the confidence bands. After the fourth quarter, the response becomes significantly positive. The response of prices to the Bank Rate shock is counterintuitive, as the restrictive monetary policy leads to a weak positive response rather than a negative response in price levels. The positive response is termed the “price puzzle” as found in many low-income countries documented in Mishra and Montiel’s (2012) study. In Botswana, this result is similar to that of Kganetsano (2007) and Setlhare (2013), who also find a positive response of prices to the Bank Rate. The possible reason for this response could be a policy change during the period. In particular, there have been changes in Botswana’s monetary policy framework and in the exchange rate regime, as elucidated in Section 2. This makes a TVP-VAR model most suitable for this analysis.

Meanwhile, the response of the nominal effective exchange rate remains unchanged from the beginning of the first quarter. It then marginally appreciates between the first and second quarter, confirming the predictions of economic theory. Nevertheless, the NEER starts to depreciate after the second quarter and stabilises from the fifth quarter, largely consistent with findings by (Bredin and O’Reilly 2014).

For comparative purposes, the results of the time-varying impulse responses, premised on the TVP-VAR model with stochastic volatility are presented in Figure 5 and Figure 6. Interestingly, all the impulse responses of the TVP-VAR model have varied more significantly than in the constant-parameter VAR impulse responses. Figure 5 shows the TVP-VAR impulse effects of a unit shock on the target variable after three-time intervals between 1994 and 2018. Impulse responses in each graph are drawn at horizon 4 months, 8 months and 1 year during the estimated period, respectively. There is an instantaneous negative response in real non-mining output to a Bank Rate shock until 2004. Thereafter, there are temporary positive responses to Bank Rate changes

for all time horizons. This may be attributable to amendments in the monetary policy structure. Another reason for the positive response of NMGDP is that the policy rate decreased around this period (expansionary monetary policy), as shown by the reaction of the Bank Rate to its own shock. Nonetheless, the overall negative response of output to a positive Bank Rate shock is theoretically intuitive and is distinct after the implementation of most liberalisation reforms (between 1994 and 2002). The trendline for the Bank Rate and output eventually dissipates.

The response of domestic prices to the Bank Rate was positive until 1999. The initial temporary price puzzle effect may be attributable to higher production costs, caused by an increment in financing as interest rates increase, or a policy change around that period. The “price puzzle” effect then dissipates as the impulse responses became negative from 2000 onwards, consistent with economic theory. The negative effect became clearer, particularly for the ‘4-months’ horizon, signifying the positive lag effects of the clear focus in 2002 on the objective of price stability in Botswana. These results confirm findings by other studies such as Mwabutwa et al. (2013) and Primeceri (2005). However, they differ from most previous studies which employed a standard VAR and found a price puzzle effect throughout their respective study periods (see Kganetsano, 2007; Ngalawa and Viega, 2011; Mishra and Montiel, 2012; Setlhare, 2013).

Similar to that of the standard VAR model, the response of the nominal effective exchange rate to a positive shock in the Bank Rate is also constant at the start of the year. The NEER then appreciates, albeit at a decreasing rate from 2001 until 2005 for all time horizons. This coincides with literature, as a positive shock in the Bank Rate will cause an appreciation of the exchange rate, which in turn, will reduce the prices of imported goods and, ultimately, the inflation rate. Consequently, this will result in increased domestic returns, and the domestic currency will depreciate to neutralise the exorbitant returns. This pattern is evident in the TVP-VAR model, as the nominal effective exchange rate begins to depreciate from 2009 onwards, consistent with the results found by Bredin and O’Reilly (2014) and Amarasekara (2008).

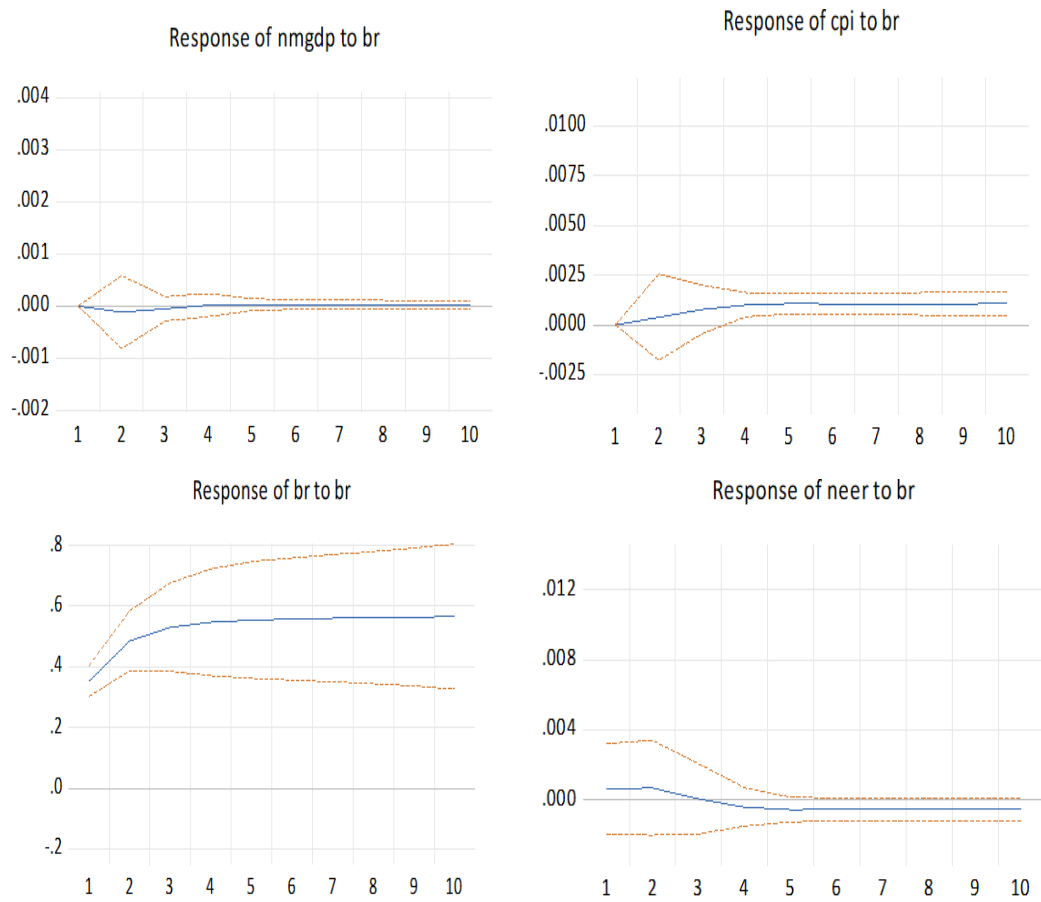
As the parameters vary over time, the impulse responses are estimated at each date over the sample period. Figure 6 shows how real non-mining GDP, CPI and the NEER

responses performed in different periods, which are arbitrarily chosen to represent the financial liberalisation reforms and structural breaks in the economy. The responses at three different dates are shown. The year 2000 captures the era of financial liberalisation or the era after the implementation of most policy reforms. This includes the intensive use of moral suasion and Primary Reserve Requirements to influence monetary conditions in the economy and hence the rate of inflation. The periods 2010 and 2015 also reflect the post-liberalisation period in Botswana. 2010 represents a post-liberalisation period after the implementation of the crawling band exchange rate mechanism in 2005, as well as the introduction and use of the medium-term objective in 2008. A price stability range was to be achieved over a medium-term horizon of 3 years. Moreover, 2010 marks a recovery period following the 2008/2009 financial crisis, which resulted in high volatility in international food and oil prices.

In Figure 6, a positive Bank Rate shock leads to an instantaneous negative response in real non-mining output for all the three arbitrary chosen periods. There is a brief positive response to Bank Rate which becomes negative from the third quarter until the end of the forecast period. The generally negative response of non-mining GDP to an increase in the Bank Rate is similar to theoretical and much of the empirical literature. There is an instantaneous negative response of prices to a monetary policy shock. This result is theoretically intuitive. The response of prices to a shock in the Bank Rate is however characterised by periods of both negative and positive responses after the initial response. This indicates that the transmission mechanism performed differently over time as a result of policy and structural changes in the monetary framework and the economy in general.

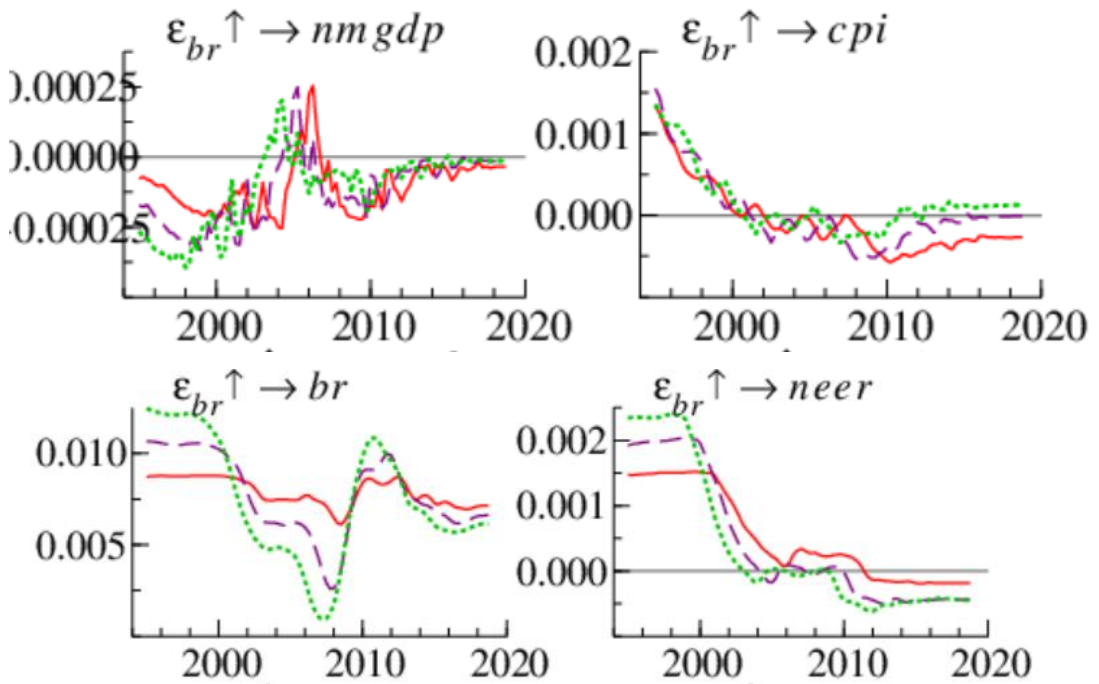
Meanwhile, the NEER appreciated for the year 2000 throughout the forecast horizon. This result is in line with economic theory. In contrast, for the 2010 and 2015 periods, the NEER appreciates promptly until the third quarter before depreciating for the rest of the time horizon. This also is in line with theory, as discussed for Figure 5.

Figure 4 Unrestricted Standard VAR Impulse Responses to a Positive Bank Rate Shock



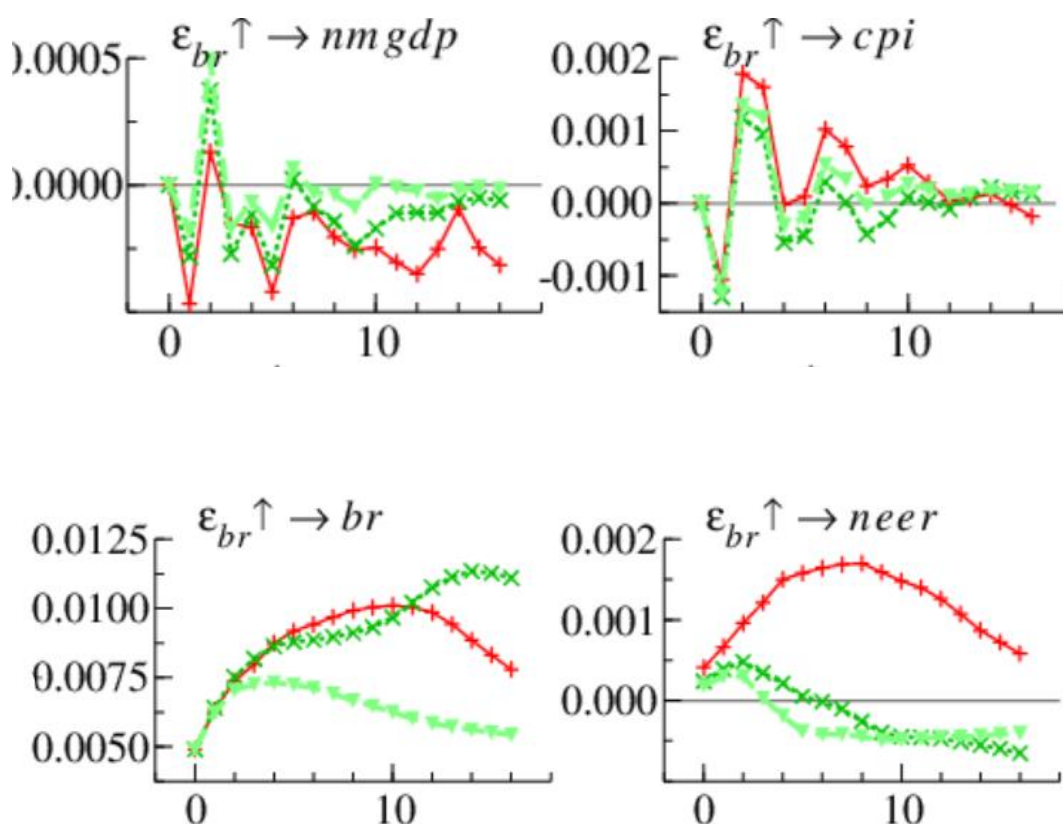
Note: Where br, nmgdp, cpi, neer represent the Bank Rate, real non-mining GDP, consumer price index and nominal effective exchange rate, respectively.

Figure 5 TVP-VAR impulses for 4 months (solid line), 8 months (dashed line) and 1 year (dotted line): Responses to a Positive Bank Rate Shock



Note: Where br, nmgdp, cpi, neer represent the Bank Rate, real non-mining GDP, consumer price index and nominal effective exchange rate, respectively.

Figure 6 TVP-VAR impulses in 2000 (red line), 2010 (dark green line) and 2015 (light green line): Responses to a Positive Bank Rate Shock



Note: Where br, nm gdp, cpi, near represent the Bank Rate, real non-mining GDP, consumer price index and nominal effective exchange rate, respectively.

A positive exchange rate shock is defined as an appreciation (Mpete, 2015). Standard VAR impulse responses (Figure 7) show that, in Botswana, the relationship between output, CPI, the Bank Rate and the nominal effective exchange rate is largely statistically insignificant. However, the expected signs to NEER shocks conform to economic theory. In particular, a positive shock in the nominal effective exchange rate leads to a negative response of real non-mining GDP, as expected. Prices also respond negatively to a positive shock in the exchange rate. CPI declines for the first four quarters before steadily returning to the base line by the fifth quarter. This implies that devaluation is inflationary in the economy.

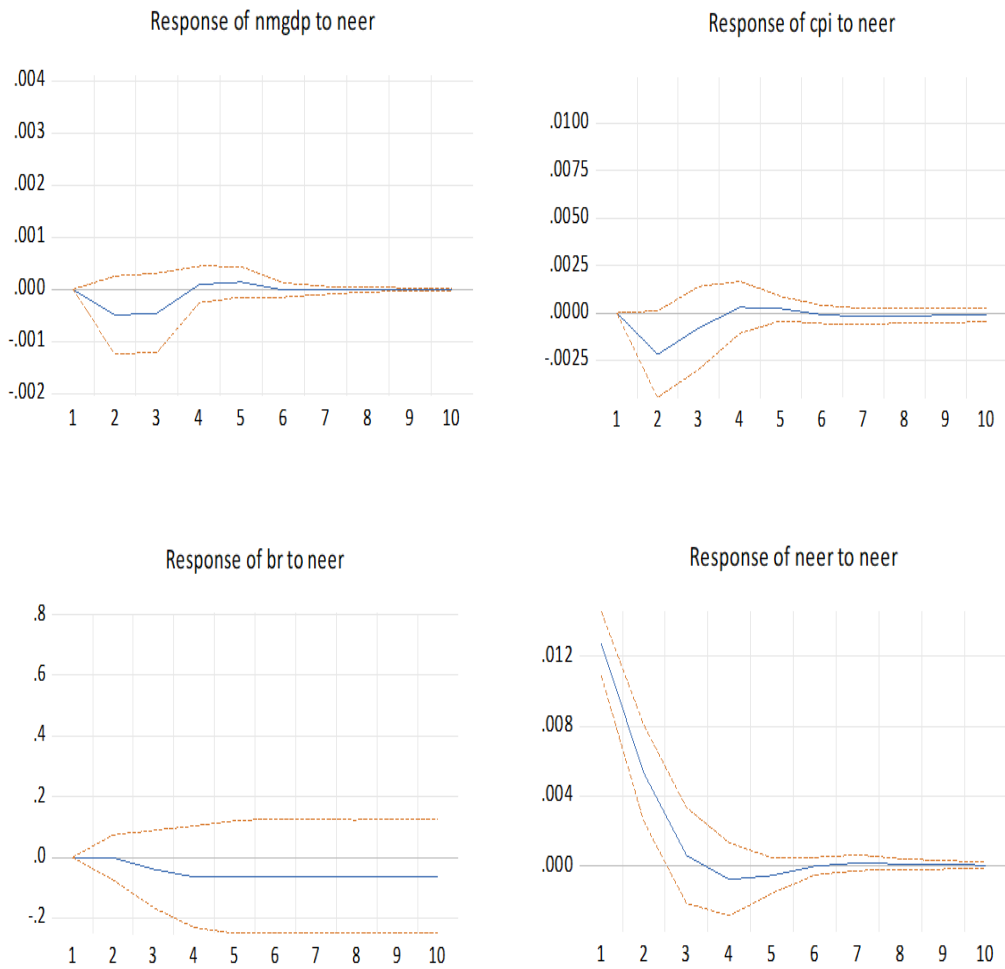
Dabla-Norris and Floerkemeier (2006) postulate that the importance of the exchange rate channel is largely influenced by the nature of exchange rate regime. As such, studies have unveiled mixed reactions of CPI and output, following exchange rate

shocks. In the case of Botswana, where the exchange rate policy has evolved over time, with room, albeit limited, for monetary authorities to intervene, mixed responses of output and inflation following a positive exchange rate shock are expected.

The results of the TVP-VAR model, displayed in Figure 8, indicate that a positive shock in the exchange rate induces a negative reaction of consumer price index in all time horizons. Although the response was negative for all time intervals, the '4 months period' responses had a relatively strong shock response. The negative response implies that an appreciation of the Pula is anti-inflationary. Consequently, currency depreciation induces inflationary pressures. The response and expected sign conform to economic theory. Botswana depends heavily on consumable imports, particularly from South Africa, and incurs high transport costs, as it is a landlocked country. As such, appreciation/depreciation shocks on NEER will influence the prices of imported products and services. The negative response on CPI is broadly in line with established empirical findings (e.g., Liu, Song and Huang, 2019; Mwabutwa et al., 2013). On the other hand, impulse response functions displayed positive responses of real non-mining output to the NEER for most periods of the study. This does not seem to be consistent with the theoretical analysis as discussed in Section 3.

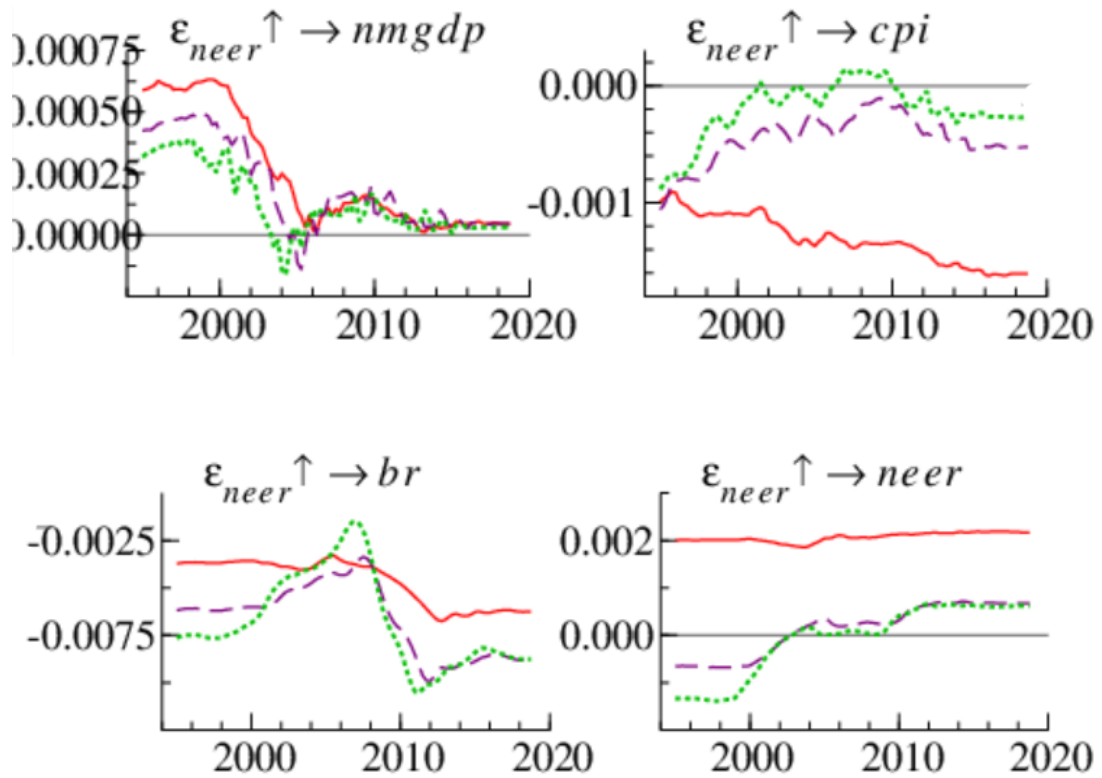
In Figure 9, a positive nominal effective exchange rate shock induces an instantaneous negative response in real-non mining GDP. This is theoretically intuitive. Nonetheless, the reaction of output to a shock in the NEER is followed by episodes of both negative and positive responses, which indicates that the transmission performed differently over time owing to policy changes in the economy. Empirical evidence has found inconclusive results in regard to the response of output to a positive shock in the exchange rate (Agenor, 1991; Akinlo and Odusola, 2003). The mixed results may be attributable to the nature of exchange rate regimes in different economies. Figure 9 also confirms that a positive shock in the NEER leads to a negative reaction of the rate of change in domestic prices for all the arbitrarily chosen periods.

Figure 7 Unrestricted Standard VAR Impulse Responses to a Positive Exchange Rate Shock



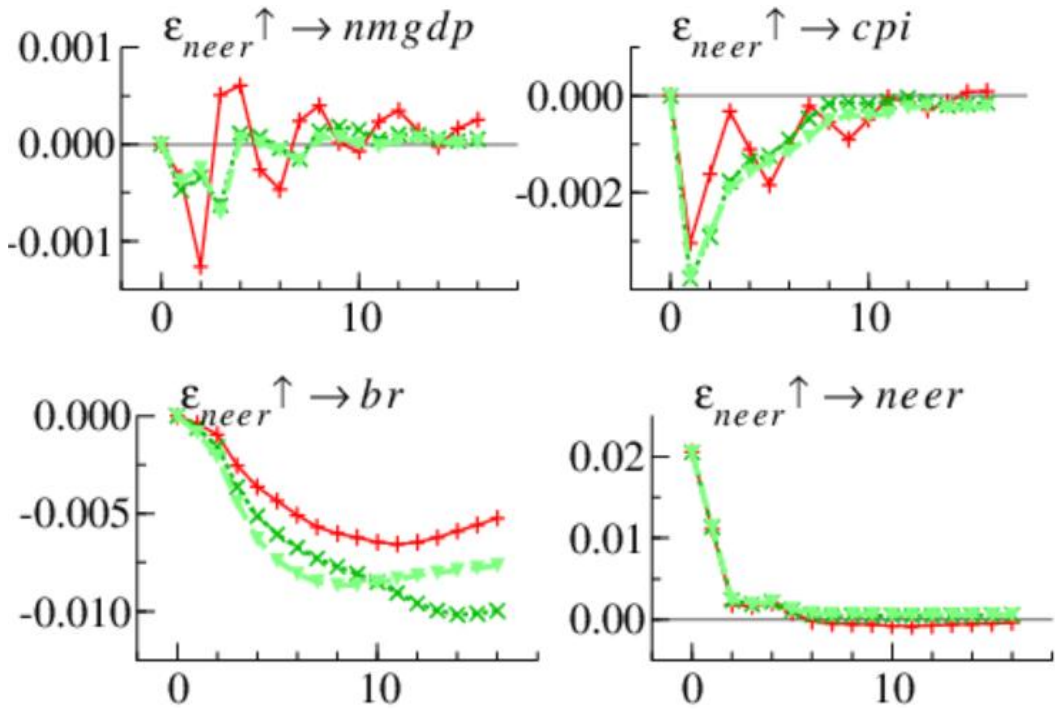
Note: Where br, nmgdp, cpi, neer represent the Bank Rate, real non-mining GDP, consumer price index and nominal effective exchange rate, respectively.

Figure 8 TVP-VAR impulses for 4 months (solid line), 8 months (dashed line) and 1 year (dotted line): Responses to a Positive Exchange Rate Shock



Note: Where br, nmgdp, cpi, neer represent the Bank Rate, real non-mining GDP, consumer price index and nominal effective exchange rate, respectively.

Figure 9 TVP-VAR impulses in 2000 (red line), 2010 (dark green line) and 2015 (light green line): Responses to a Positive Exchange Rate Shock



Note: Where br, nmgdp, cpi, neer represent the Bank Rate, real non-mining GDP, consumer price index and nominal effective exchange rate, respectively.

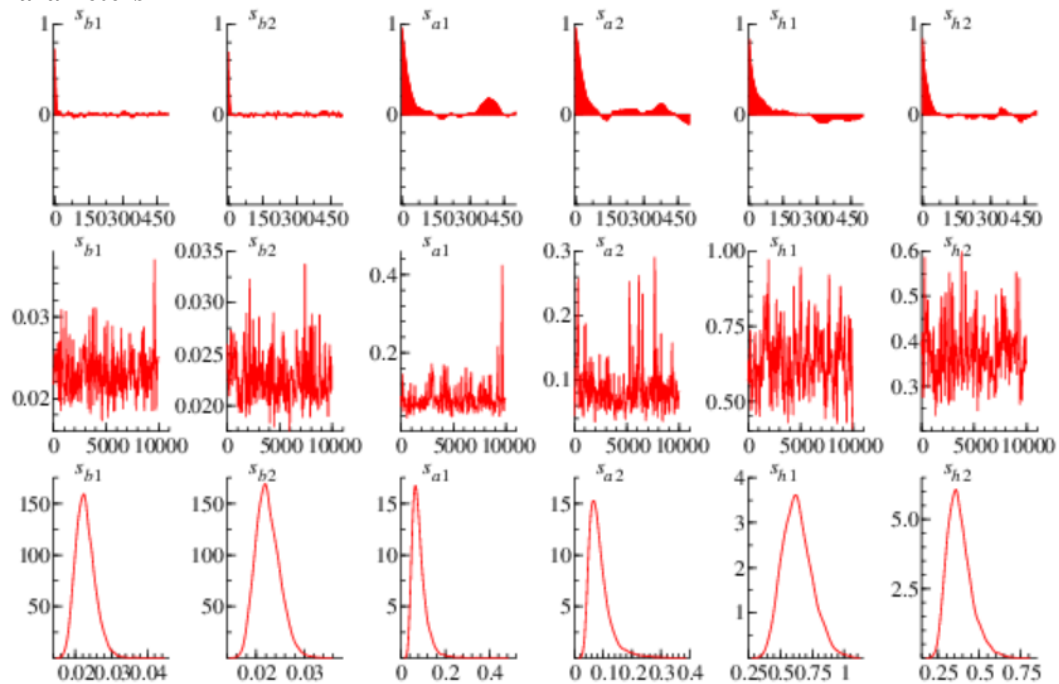
We now look at the model with private credit. The TVP-VAR estimates for the second model (which is ordered as: real non-mining GDP, consumer price index, private credit, Bank Rate) are presented in Table 6. The table shows estimates for the posterior means, posterior standard deviation, 95% credible intervals, the Geweke convergence diagnostics (CD) and the inefficiency factors, all of which are estimated using MCMC sample (Nakajima, 2011).

The results indicate that all Geweke CD values are less than unity, implying that the null hypothesis of convergence to the posterior distribution is not rejected. The results also indicate an efficient sampling of posterior draws as the inefficient factors are below 100. Furthermore, the estimated posterior mean for each parameter falls within their respective 95% credible intervals. This implies that the estimated posterior means are close to the true value of the parameters and, in turn, suggests that the MCMC algorithm produces efficient posterior distribution.

Table 6 Estimation of Selected Parameters in the TVP-VAR Model

Parameter	Mean	Stdev	95%L	95%U	Geweke	Inef.
sb1	0.0228	0.0027	0.0184	0.0288	0.429	6.85
sb2	0.0224	0.0025	0.0182	0.0278	0.268	4.33
sa1	0.0830	0.0359	0.0419	0.1662	0.003	54.58
sa2	0.0871	0.0385	0.0433	0.1939	0.162	61.96
sh1	0.6346	0.1150	0.4356	0.8836	0.040	48.30
sh2	0.3799	0.0738	0.2670	0.5562	0.145	26.66

As shown in Figure 10, autocorrelations in the first row of every figure all drop steadily and range somewhat close to the 0 level, indicating that the sample path is quite steady. This suggests that the sampling technique generates samples with negligible autocorrelation. Additionally, the sample paths in the subsequent panel were all relatively stable, suggesting that the samples resulting from the MCMC method were efficient. Lastly, the posterior densities in the third panel imply that the MCMC estimations lead to stable samples.

Figure 10 Sample Autocorrelation, Sample Paths and Posterior Densities for Selected Parameters

Note: The Figure shows sample autocorrelations (top), sample paths (middle) and posterior densities (bottom).

Figure 11 illustrates the responses of output, prices, and the Bank Rate to a positive private credit shock in a standard VAR model. The response of real non-mining GDP is insignificant and mostly counterintuitive. Impulse responses fluctuate around the zero line, before they decrease from the second quarter to the third quarter. There is a positive response of NMGDP to credit, from the fourth to the fifth quarter, although it is marginal. Thereafter, the impulse responses dissipate. This indicates that the effect of private credit, when using a standard VAR model, is quite short-lived. This conclusion is buttressed by Setlhare (2013).

Inflation decreases as credit increases from the first quarter to the second quarter. This is counterintuitive because a surge in private credit is expected to increase inflation. However, inflation starts to increase from the second quarter and becomes positive from the third quarter. The positive response is nonetheless marginal and is found around the zero line.

Figure 12 of the TVP-VAR model depicts substantial variation in NMGDP responses after a one standard deviation positive private credit shock, especially for the '4-months' interval. The '8-months' and the '1-year ahead' trajectories respond positively by fluctuating around the zero line. The real NMGDP increases based on an increase in credit, indicating that increasing credit increases economic activity. Thus, the finding is consistent with economic theory and most established empirical work (for example, Mwabutwa et al., 2013 and Kganetsano, 2007).

Inflation responds generally positively to a positive private sector credit shock. The 4-months lag instantaneous response is negative but starts to increase and becomes positive from 1996. It also becomes temporarily negative before picking up between 2000 and 2002. Meanwhile, the 8-months and 1-year lags respond generally positively for most of the sample period. This is expected as growing credit induces economic activity, which will, in turn, increase aggregate demand and inflation.

Lastly, monetary policy tightening induces an instantaneous decline in credit for the 8-months and 1-year lag, consistent with economic theory. Surprisingly, credit begins to rise from 2000, consistent with results found by Kganetsano (2007). This

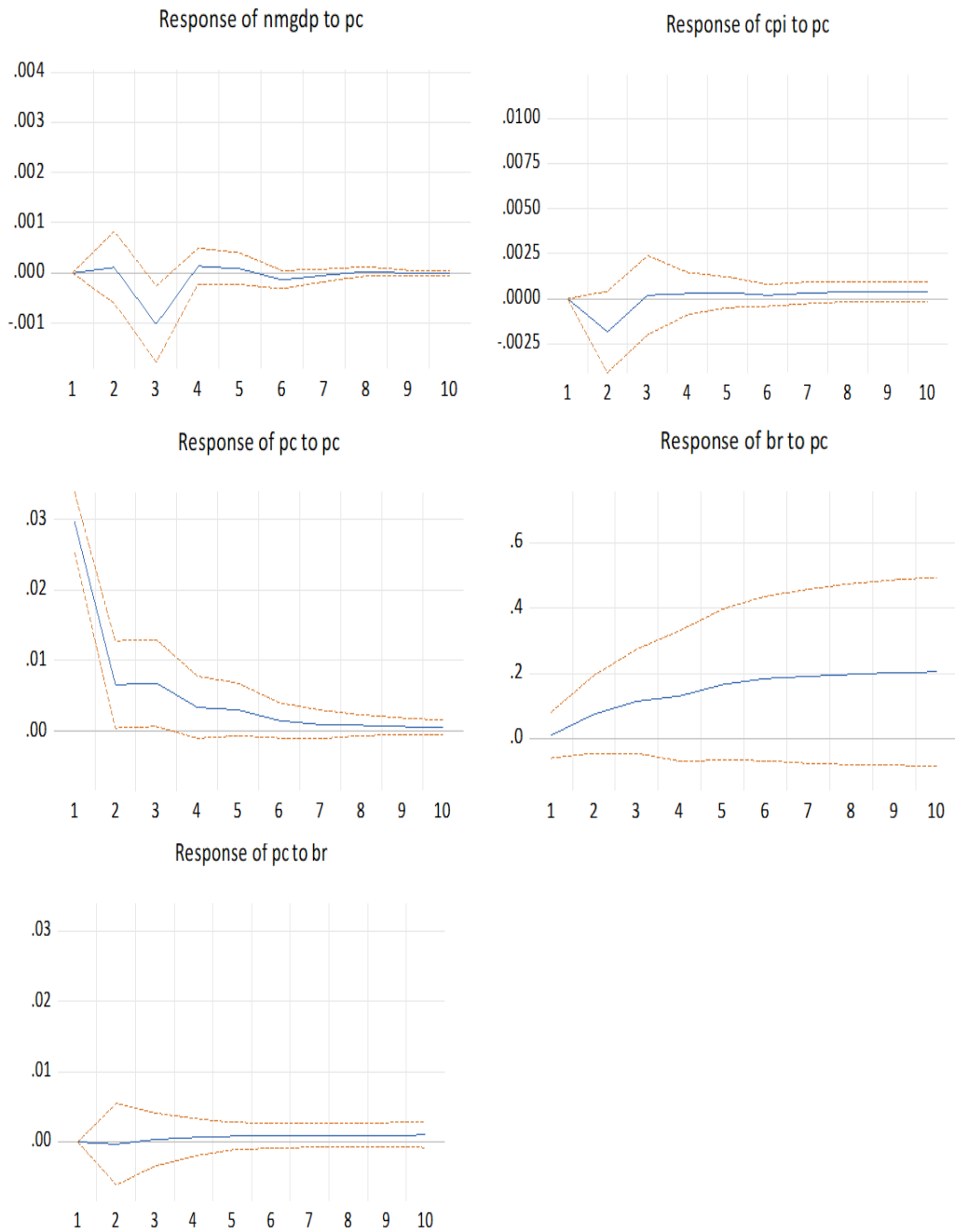
counterintuitive result could be due to competitive loan schemes. This results in the growth of credit, not reflecting the true level of private demand in the economy.

Figure 13, shows how the responses of output, prices and the Bank Rate behaved in the arbitrarily chosen dates in order to capture the financial liberalisation reforms or structural breaks in the economy. The year 2004 captures a post-liberalisation era for most policy reforms. This period coincides with the decision by Bank of Botswana to devalue the Pula by 7.5 percent in first quarter of 2004. It is also against a background of the introduction of the Value Added Tax in Botswana in 2002. Furthermore, this period marks the commencement of a clear focus on the price stability objective in Botswana in 2002 (Bank of Botswana, 2002). The period 2012-2016 is still a post-financial liberalisation era, but 2012 particularly reflects a significant VAT increase to 12% in 2011.

A positive credit shock induces an instantaneous positive response in real non-mining output until the end of the first quarter for all the arbitrarily chosen periods, consistent with theoretical literature. Thereafter, there is a temporary negative response to credit changes for a quarter before it becomes positive for the rest of the time horizon. However, the responses fluctuate around the zero line, which show a limited impact of credit on output. The result possibly indicates the relatively less robust financial structure in Botswana, despite financial liberalisation reforms.

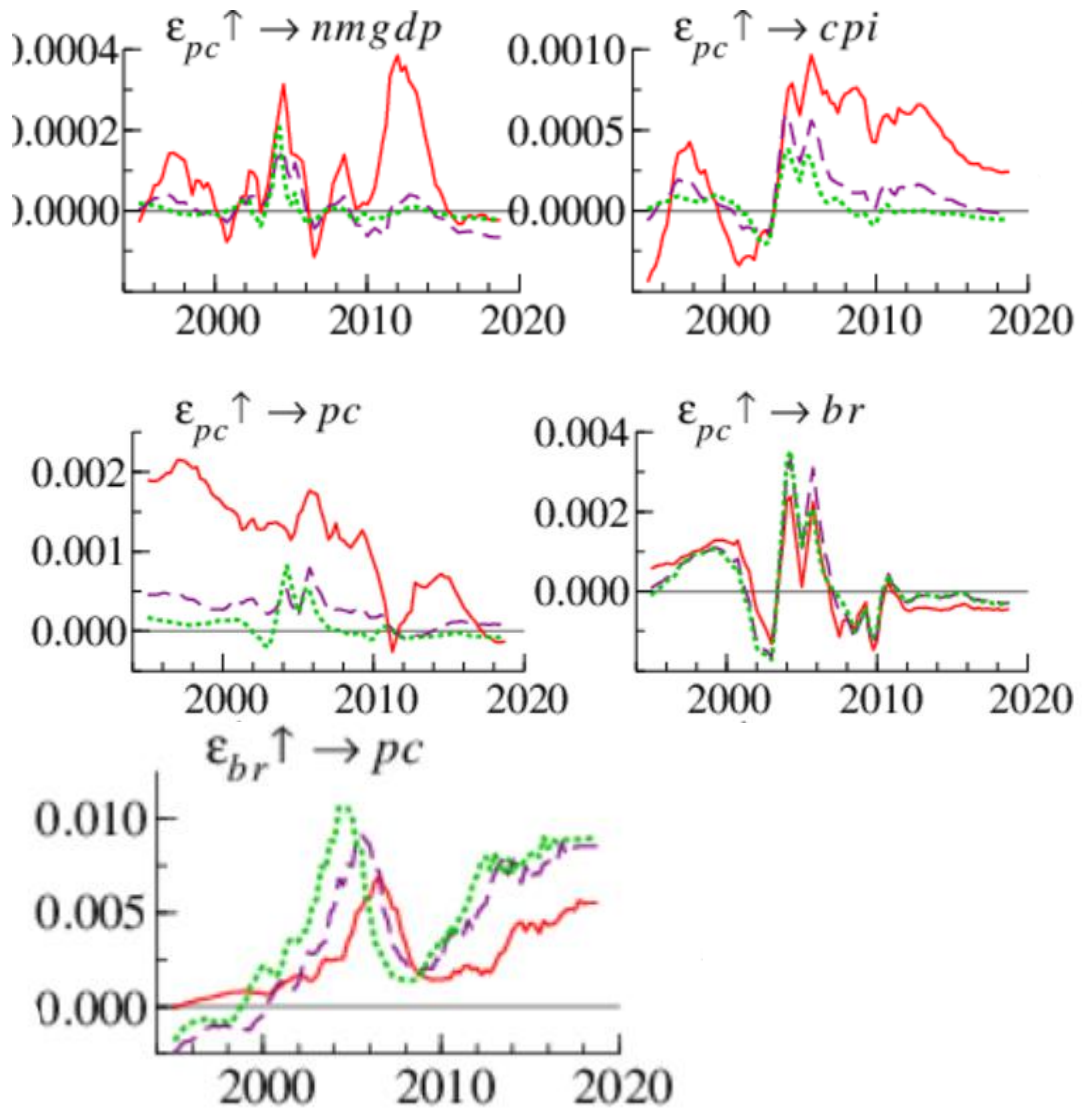
We observe a negative instantaneous response of prices to the credit shock. After quarter one, the empirical reaction becomes positive for all the chosen periods. This result indicates that the response is inflationary, which is theoretically intuitive.

Figure 11 Unrestricted standard VAR Impulse Responses to a Positive Private Credit Shock



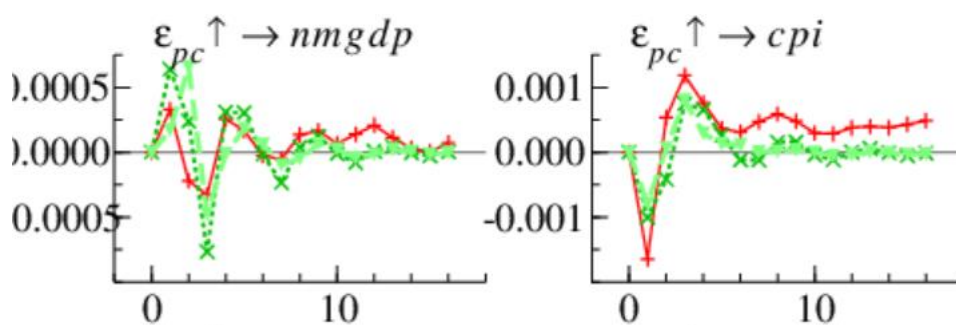
Note: Where br, nmgdp, cpi, pc represent the Bank Rate, real non-mining GDP, consumer price index and private credit, respectively.

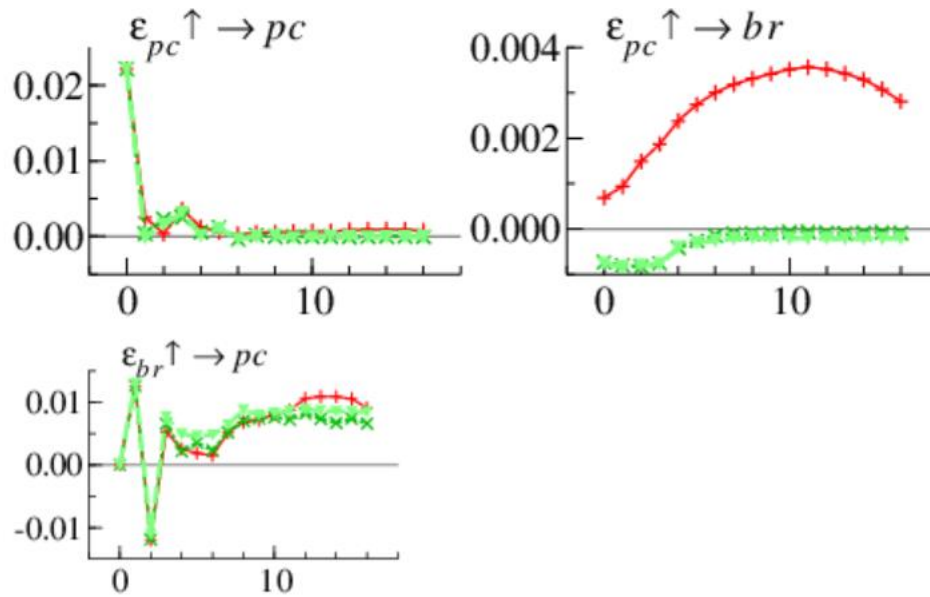
Figure 12 TVP-VAR impulses for 4 months (solid line), 8 months (dashed line) and 1 year (dotted line): Responses to a Positive Private Credit Shock



Note: Where br, nmgdp, cpi, pc represent the Bank Rate, real non-mining GDP, consumer price index and private credit, respectively.

Figure 13 TVP-VAR impulses in 2004 (red line), 2012 (dark green line) and 2016 (light green line): Response to a Positive Private Credit Shock





Note: Where br, nmgdp, cpi, pc represent the Bank Rate, real non-mining GDP, consumer price index and private credit, respectively.

In summary, the overall impulse responses in this section suggest that the transmission mechanism performed differently over time owing to the policy and structural changes of the financial liberalisation period. The research also establishes that the transmission mechanism becomes clearer and improves for the TVP-VAR models compared with the constant-parameter VAR models due to the structural changes in the economy.

5.6 Diagnostic tests

To confirm the efficiency and reliability of the VAR models, we report a series of diagnostic and stability tests. These tests report the statistical adequacy of the estimated models. We fail to reject the null hypothesis of no serial correlation and stability of estimated coefficients for the two models. The estimated VAR models show the absence of model misspecification, serial correlation and non-normality of residuals (Figure 3 and Figure 10).

The stability test is important, and therefore conducted because an unstable VAR model will lead to invalid impulse responses. The stability of the models was confirmed using the inverse roots of the characteristic AR polynomial. Figures A1 and A2 in the Appendix show that the VAR models meet the stability conditions, given that all roots lie inside the unit circle for both models.

6 CONCLUSION

This study analyses the evolution of the monetary policy transmission mechanism in Botswana by using a time-varying parameter model. It estimates a TVP-VAR model, where the time variations derive from the coefficients and the variance-covariance matrix of the model's innovations. The TVP-VAR model generates dynamic impulse responses in non-mining GDP, NEER and consumer price index to the monetary policy shocks in Botswana from 1994Q1 to 2018Q4. Botswana provides a good context for assessing the monetary policy over time, following structural and macroeconomic reforms undergone since 1989. As such, this study fills a literature gap by capturing the time-varying aspect of the economy and the changes in the transmission mechanism over time using a TVP-VAR model with stochastic volatility.

The TVP-VAR impulse responses reveal more detail and show greater variability for the non-mining GDP and consumer price index responses to monetary policy shocks, than the constant parameter VAR impulse responses. Moreover, the constant parameter VAR model has found it difficult to establish evidence of the effect of monetary policy innovations on output and inflation because of insignificant and counterintuitive results. These constant parameter VAR model results coincide with evidence found by Mishra and Montiel (2002). The main flaw of the constant VAR model is that it cannot capture probable non-linearity or time variation in the lag structure of the model, and therefore cannot capture non-linearity in relationships between the variables of the model. This confirms the need to use the TVP-VAR model.

The TVP-VAR model shows evidence of time variation in Botswana's monetary policy following policy changes in the economy. In particular, the monetary policy transmission performed broadly in line with standard theory, as shown by the relatively robust interest rate and exchange rate channels. Importantly, the results indicate a minimal issue of price puzzle, contrary to existing literature on Botswana and most developing countries. These results show the superiority of the TVP-VAR model over the traditional VAR model.

On the other hand, the credit channel behaved in line with economic theory, except for the counterintuitive effect of a positive shock of the Bank Rate on private credit. In line with this result, further robust development of Botswana's financial market, with more financial innovations, is recommended. This will lead to more investment and the growth of the economy. Finally, this study did not explore the asset price channel because of a lack of consistent data and of the less-developed capital market in Botswana. This could be an area for future study. One limitation of this study is the absence of a long time series data set. Such data would allow the transmission of monetary policy during both the financial repression and financial liberalisation periods to be assessed.

REFERENCES

Acosta-Ormaechea, S., and Coble, D. (2011). Monetary transmission in dollarized and non-dollarized economies: The cases of Chile, New Zealand, Peru and Uruguay. IMF Working Paper, wp/11/87 (Washington: International Monetary Fund).

Agenor, P. R. (1991). Output, devaluation and the real exchange rate in developing countries. *Review of World Economics*, 127(1), 18-41.

Akinlo, A., and Odusola, A. (2003). Assessing the impact of Nigeria's naira depreciation on output and inflation. *Applied Economics*, 35(6), 691-703.

Amarasekara, C. (2008). The impact of monetary policy on economic growth and inflation in Sri Lanka. MPRA Paper No. 64866. Central Bank of Sri Lanka.

Bank of Botswana (BoB), Annual Reports, 1993, 2000, 2009, Bank of Botswana.

Bank of Botswana Monetary Policy Statement (2012), Bank of Botswana.

Bernanke, B. (1990). The federal funds rate and the channels of monetary transmission. 0898-2937. National Bureau of Economic Research.

Bernanke, B. S., and Gertler, M. (1995). Inside the black box: the credit channel of monetary policy transmission. *Journal of Economic Perspectives*, 9(4), 27-48.

Blanchard, O. J., and Fischer, S. (1989). Lectures on macroeconomics. MIT press.

Bredin, D., and O'Reilly, G. (2004). An analysis of the transmission mechanism of monetary policy in Ireland. *Applied Economics*, 36(1), 49-58.

Clark, T. E., and McCracken, M. W. (2008). Forecasting with Small Macroeconomic VARs in the Presence of Instabilities. *Frontiers of Economics and Globalisation*, 3, 93-147.

Dabla-Norris, M. E., and Floerkemeier, H. (2006). Transmission mechanisms of monetary policy in Armenia: evidence from VAR analysis. IMF Working Paper, wp/06/248 (Washington: International Monetary Fund) .

Hicks, J. R. (1973). Capital and time: a neo-Austrian theory. Oxford University Press.

Holtemöller, O. (2003). Money stock, monetary base and bank behavior in Germany/Geldmenge, Geldbasis und Bankenverhalten in Deutschland. *Jahrbücher für Nationalökonomie und Statistik*, 223(3), 257-278.

Höppner, F., Melzer, C. and Neumann, T. (2008). Changing effects of monetary policy in the US—Evidence from a time-varying coefficient VAR. *Applied Economics*, 40(18), 2353-2360.

Keho, Y. (2011). Long-Run Determinants of Savings Rates In Waemu Countries: An Empirical Assessment From Ardl Bounds Testing Approach. *South African Journal of Economics*, 79(3):312-329.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. New York: Harcourt Brace Publishers.

Kganetsano, T. A. (2007). *The transmission mechanism of monetary policy in Botswana: A Doctoral Thesis*. Loughborough University, United Kingdom.

Koop, G., and Korobilis, D. (2010). Bayesian multivariate time series methods for empirical macroeconomics. *Foundations and Trends in Econometrics*, 3(4), 267-358.

Korobilis, D. (2013). Assessing the transmission of monetary policy using time-varying parameter dynamic factor models. *Oxford Bulletin of Economics and Statistics*, 75(2), 157-179.

Lange, R. H. (2010). Regime-switching monetary policy in Canada. *Journal of Macroeconomics*, 32(3), 782-796.

Levine, R. (1997). Financial Development and Economic Growth: Views and Agenda. *Journal of Economic Literature*, 35, 688-726.

Liu, C., Song, P. and Huang, B. (2019). The dynamic effectiveness of monetary policy in China: evidence from a TVP-SV-FAVAR model. *Applied Economics Letters*, 26(17), 1402-1410.

Ma, Y., and Lin, X. (2016). Financial development and the effectiveness of monetary policy. *Journal of Banking Finance*, 68, 1-11.

McKinnon, R. I. (1973). *Money and capital in economic development*. Brookings Institution, Washington, DC.

Mies, V., and Tapia, M. (2003). *Monetary Policy Transmission Mechanism in Chile: Has the effect of Monetary Policy Changed in Time? Why? (Online Document)* http://www.cemla.org/org/pdf/redviii/chile_mies_tapia.pdf. (12/12/2019).

Mishkin, F. S. (1995). Symposium on the monetary transmission mechanism. *Journal of Economic Perspectives*, 9(4):3-10.

- Mishra, P. and Montiel, P. (2012). How effective is monetary transmission in low-income countries? A survey of the empirical evidence. IMF Working Paper No. 12/143.
- Mpete, E.M., (2015). The Impact of Exchange Rate Devaluations on Inflation and Output in Botswana. *Bank of Botswana Research Bulletin*, 28 (1), 9-22. www.bob.bw.
- Mwabutwa, C., Bittencourt, M. and Viegi, N. (2013). Evolution of monetary policy transmission mechanism in Malawi: A TVP-VAR Approach. University of Pretoria, Department of Economics, Working Paper Series (2013/27)
- Nakajima, J. (2011). Time-varying parameter VAR model with stochastic volatility: An overview of methodology and empirical applications. *Institute of Monetary and Economic Studies*, Discussion Paper No. 2011-E-9, Bank of Japan.
- Nakajima, J., Kasuya, M. and Watanabe, T. (2011). Bayesian analysis of time-varying parameter vector autoregressive model for the Japanese economy and monetary policy. *Journal of the Japanese International Economies* 25(3), 225-245.
- Nakajima, J., and Watanabe, T. (2011). Bayesian analysis of time-varying parameter vector autoregressive model with the ordering of variables for the Japanese economy and monetary policy. Global COE Hi-Stat Discussion Paper series No:196. *Institute of Economics Research*, Hitotsubashi University.
- Ngalawa, H., and Viegi, N. (2011). Dynamic effects of monetary policy shocks in Malawi. *South African Journal of Economics*, 79(3), 224-250.
- Owusu-Sekyere, E. (2017). The impact of monetary policy on household consumption in South Africa: Evidence from vector autoregressive techniques. *South African Journal of Economic Management Sciences*, 20(1), 1-14.
- Peersman, G., and Smets, F. (2001). The monetary transmission mechanism in the Euro area: more evidence from var analysis. Working Paper Series 091, European Central Bank.
- Prasad, A., and Espinoza, R. A. (2012). Monetary policy transmission in the GCC countries. IMF Working Paper, wp/12/132.
- Primiceri, G. E. (2005). Time varying structural vector autoregressions and monetary policy. *The Review of Economic Studies*, 72(3), 821-852.
- Setlhare, L. (2013). The Monetary Transmission Mechanism in Botswana: A Structural Vector Auto-Regression Approach. *Bank of Botswana*, 26(1), 37-48.
- Shaw, E. S. (1973). *Financial deepening in economic development*. New York: Oxford University Press.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: Journal of the Econometric Society*, 48(1), 1-48.

Smal, M., and de Jager, S. (2001). The monetary transmission mechanism in South Africa. South African Reserve Bank, Pretoria.

Tsangarides, M. C. G. (2010). Monetary policy transmission in Mauritius using a VAR analysis. International Monetary Fund.

Zivot, E., and Andrews, D. (1992). Further evidence on the great crash, oil prices shock and the unit root hypothesis. *Journal of Business and Economics Statistics*, 10(3), 251-270.

APPENDIX

Table A 1 Descriptive Statistics

	LNMGDP	LCPI	LPC	LNEER	BANK_RATE
Mean	2.229394	3.912907	9.226384	4.818360	11.52510
Median	2.219909	3.957823	9.202741	4.769688	13.00000
Maximum	2.303118	4.609050	10.95383	5.151835	15.50000
Minimum	2.145608	2.925218	7.407621	4.601639	5.000000
Std. Dev.	0.045429	0.535751	1.189514	0.189810	3.333471
Skewness	0.056332	-0.204183	-0.117909	0.136905	-0.725942
Kurtosis	1.740125	1.666677	1.685790	1.353394	2.104291
Jarque-Bera Probability	6.666576 0.035676	8.102142 0.017404	7.428160 0.024378	11.60951 0.003013	12.12608 0.002327
Sum	222.9394	391.2907	922.6384	481.8360	1152.510
Sum Sq. Dev.	0.204317	28.41588	140.0794	3.566771	1100.091
Observations	100	100	100	100	100

Table A 2 Correlation Matrix

	LNMGDP	LCPI	LPC	LNEER	BANK_RATE
LNMGDP	1.000000				
LCPI	0.984470	1.000000			
LPC	0.982129	0.994133	1.000000		
LNEER	-0.963990	-0.967672	-0.950767	1.000000	
BANK_RATE	-0.799920	-0.717716	-0.737477	0.716768	1.000000

Table A 3 VIF test

	Coefficient	Centered
Variable	Variance	VIF
LCPI	0.000162	177.5046
LNEER	0.000151	20.77451
LPC	2.29E-05	123.6558
BANK_RATE	5.93E-08	2.518868
C	0.005290	NA

Table A 4 Quandt-Andrews Breakpoint test

Statistic	Value	Prob.
Maximum LR F-statistic (2002Q1)	28.82122	0.0000
Maximum Wald F-statistic (2002Q1)	115.2849	0.0000
Exp LR F-statistic	11.76469	0.0000
Exp Wald F-statistic	54.05318	0.0000
Ave LR F-statistic	13.76857	0.0000
Ave Wald F-statistic	55.07427	0.0000

Note: probabilities calculated using Hansen's (1997) method

Table A 5 Chow test

F-statistic	28.82122	Prob. F(4,92)	0.0000
Log likelihood ratio	81.23054	Prob. Chi-Square(4)	0.0000
Wald Statistic	115.2849	Prob. Chi-Square(4)	0.0000

Table A 6 Quandt-Andrews Breakpoint test (For model that includes credit)

Statistic	Value	Prob.
Maximum LR F-statistic (2002Q1)	37.66596	0.0000
Maximum Wald F-statistic (2002Q1)	150.6638	0.0000
Exp LR F-statistic	15.88738	0.0000
Exp Wald F-statistic	71.91172	0.0000
Ave LR F-statistic	18.19453	0.0000
Ave Wald F-statistic	72.77812	0.0000

Note: probabilities calculated using Hansen's (1997) method

Table A 7 Chow test (For model that includes credit)

F-statistic	24.61563	Prob. F(4,91)	0.0000
Log likelihood ratio	72.59983	Prob. Chi-Square(4)	0.0000
Wald Statistic	98.46250	Prob. Chi-Square(4)	0.0000

Table A 8 Lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	165.3462	NA	3.52e-07	-3.507527	-3.397884	-3.463274
1	848.7955	1292.611	1.76e-13	-18.01729	-17.46908*	-17.79603
2	878.4805	53.56199	1.31e-13*	-18.31479*	-17.32801	-17.91652*
3	887.6372	15.72568	1.53e-13	-18.16603	-16.74067	-17.59074
4	902.8269	24.76593	1.57e-13	-18.14841	-16.28448	-17.39611
5	916.0077	20.34422	1.70e-13	-18.08712	-15.78462	-17.15781
6	930.4029	20.96692	1.80e-13	-18.05224	-15.31116	-16.94592
7	950.0957	26.97051	1.71e-13	-18.13251	-14.95287	-16.84918
8	970.6093	26.31093*	1.62e-13	-18.23064	-14.61242	-16.77029

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Figure A 1
Inverse Roots of AR Characteristic Polynomial

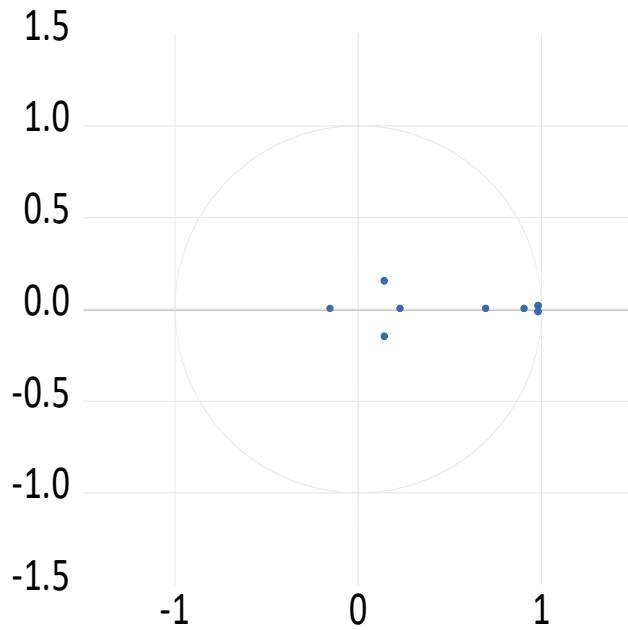


Table A 9 Lag order selection criteria (For model that includes credit)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	239.4590	NA	7.03e-08	-5.118674	-5.009031	-5.074421
1	915.3522	1278.320	4.14e-14	-19.46418	-18.91596*	-19.24291
2	943.5469	50.87301	3.18e-14*	-19.72928*	-18.74249	-19.33100*
3	950.1446	11.33092	3.93e-14	-19.52488	-18.09952	-18.94960
4	961.3270	18.23214	4.40e-14	-19.42015	-17.55622	-18.66785
5	971.0478	15.00382	5.12e-14	-19.28365	-16.98115	-18.35434
6	989.9092	27.47207*	4.93e-14	-19.34585	-16.60478	-18.23953
7	1006.843	23.19190	4.99e-14	-19.36615	-16.18651	-18.08282
8	1024.256	22.33436	5.06e-14	-19.39687	-15.77866	-17.93653

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Figure A 2
Inverse Roots of AR Characteristic Polynomial

