Financial Innovations’ Impact in Monetary Policy Transmission Mechanism in Tanzania.

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経済学専攻

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(タンザニアにおける金融イノベーションが金融政策の効果に与える影響について)

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Abstract

Tanzania's financial system has experienced notable development of its payment infrastructures in the recent past. The changes have been accelerated by innovations related to IT. These developments have altered the way people used to interact with money and financial institutions, thus resulting in potential implications on the conduct of monetary policy monetary and its transmission mechanisms.

Since these changes came into play, theoretically, some works of literature are predicting how the future monetary policy might be, however, there exists limited empirical evidence, particularly in Tanzania. This paper addresses this empirical gap by examining the effect of FinTech, particularly mobile money on monetary policy.

By using the structural VAR model splitting data set into two sets, before and after the introduction of mobile money. Generally, results show a weak monetary policy transmission mechanism but a slight improvement in the sample after the introduction of mobile money. Whereby output and inflation have a stronger reaction to monetary policy innovations. Also, by using the Markov Switch VAR model, results indicate monetary policy changed regime around 2013, by being relatively effective.

The constant parameter DSGE model is modified with transaction cost that captures the effect of mobile money. The simulations results show expansionary policy shock under lower transaction cost leads to stronger decrease real interest rates thus higher increase in both poor and rich consumption, output, and Inflation. This implies that the monetary policy transmission mechanism has changed to be more effective to impact real variables.

Estimated regime-switching DSGE models show the monetary policy has switched from less effective to more effective regime in 2013. The estimated model fits better Tanzanian data and transaction cost parameters are well identified except for transaction cost for Poor households which is associated with the data used.

The introduction of mobile money has led to greater financial inclusion that has changed the behavior of firms and consumers from lower transaction costs in ways that have improved the effectiveness of the monetary policy.

Keywords: Financial Technologies; Monetary Policy; VAR; TANK Model, Regime Switch; Mobile Money, Mobile Network Operators (MNO's) and Transaction costs.

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Chapter 1

Introduction

1.1 Background

Information technology innovations have enhanced Financial Technologies (Fintech), thus the evolution of money from barter trade and commodity money, then coins to paper money; paper to cheques and cards, and recently electronic and digital currency. The application of FinTech cuts across multiple business segments such as e-commerce, online lending platforms, payment systems such as PayPal, Mobile payment (M-Money/Mpesa) and internet banking.

These changes have increased transparency, reduced transaction costs, thus directly impact on the price-setting behavior by businesses, Kobrin (1997) and Friedman (1999). The proliferation usage of electronic money and advancement in payment systems poses a challenge to the central bank's functions of supervisory and conducting monetary policy thus warranties thorough review.

Financial technology refers to the use of technology to deliver financial solutions. FinTech has evolved in three generations, the first one was marked with the interaction between technology and finance being enhanced by infrastructure advancement of global telex network.

The second was the digitization of traditional financial services that was characterized by the use of ATMs in the 1970s and online banking and key players were the banks. The third regime can be viewed as bottom-up since the first two eras started in developed countries and later to the developing countries. This era happened to both developing and developed countries simultaneously, the main drivers being Information Technology (IT) firms and start-ups,Arner et al. (2017).

The developments in telecommunication have made mobile technology flourish throughout the developing world faster than any other technology in history. The most impressive product being M-Money that has allowed millions of previously underserved people to safely send and receive money, pay bills for goods and services without relying exclusively on cash Nyamongo and Ndirangu (2013).

In Tanzania, this form of electronic money came into use for the first time in 2007. The key players in making the mobile money fully operational are regulators; the Bank of Tanzania (BoT) and Tanzania Communications Regulatory Authority (TCRA), Mobile Network Operators (MNOs), and commercial banks. The mobile money main lines of transactions are; cash deposits 30.68%, withdrawals 29.13%, Person to Person payments 18.92%, and 12.4% for bill payments. In terms of users at least 62 percent of mobile phone subscribers use mobile money.

Mobile money has become very popular in recent days and significantly changed the traditional way people used to interact with money and financial institutions. Therefore this paper is aiming at addressing the question, whether there have been monetary policy structural changes in affecting the real economy after the introduction of mobile money. This is because mobile money has increased money velocity and multiplier. The classical quantity theory assumes the velocity of money to be constant, and its important component for the monetary policy framework that uses monetary aggregate targets, to be able to deliver its objective.

1.2 Financial Sector and Mobile Money in Tanzania

An overview of financial sector developments in Tanzania can be marked from the 1990s, where the sector started to experience series of fundamental changes. Before the 1990s financial sector was dominated by state-owned financial institutions which were underperforming, and thus led to First-Generation Financial Sector Reforms (FGFSR) in 1990. In order to improve the sector performance, Banking and Financial Institutions Act was enacted in 1991 that allowed entry of private banks and financial institutions, both domestic and foreign. In 1992, Foreign Exchange Act was enacted which led to the liberalization of foreign exchange rates and interest rates.

The Bank of Tanzania (BoT) Act was enacted in 1995, the act changed the Bank from multiple policy objectives to a single objective of price stability. During this period and notable developments amongst others were the introduction of ATM, the establishment of capital markets and stock exchange, liberalization of financial markets thus paved a way for transitioning monetary policy from using direct to indirect market-based instruments and shifted from targeting M3 to M2 as an intermediate target. In terms of payment infrastructure, there were establishments of the electronic clearinghouse, Inter-Bank Settlement System (TISS), and Electronic Fund Transfer (EFT) system.

In 2003 the joint IMF/World Bank mission under Financial Sector Assessment Programme (FSAP), resulted in the Second-Generation Financial Sector Reforms (SGFSR) which were approved in 2006. The objective was to strengthen the banking, insurance, and financial markets sectors by boosting structures and institutional arrangements to accelerate the functioning of a market economy. Monetary policy operational target changed from reserve money of which targets were set as the stocks of reserve money at the end of each month to average reserve money for the month aiming at evenly spreading of policy actions and ensure low volatility in money market rates and liquidity.

The SGFSR package was in line with the Bank of Tanzania Act of 2006 under section 6, which requires the Central Bank to conduct oversight functions on the payment, clearing, and settlement systems in any bank, financial institution, or infrastructure service provider. This extension of oversight of the payments providers to include non-financial institutions allowed a start-up like E-Fulusi Africa Ltd. to seek the permission of launching the new mobile money in 2007. Bank had not yet defined rules for electronic payment schemes, thus responded by providing Electronic Payment Scheme Guidelines in the same year.

The guidelines did not fully incorporate the roles of non-financial institutions, thus prompted the bank to allow these types of institutions to launch their own payments services through the issuance of letters of no objection (LNOs) platform. In 2008, Tanzania launched it's first mobile money "Mobipawa" when E-Fulusi was granted an LNO. Which permitted non-financial institutions to launch their payments under BoT oversight, provided they would keep customers' electronic money float in a trust account with a licensed commercial bank.

E-Fulusi sold its service to Zantel, which was the first Mobile Network Operator (MNO) to launch mobile money known as "Z-Pesa". This paved the way for other MNO in the same line of business such as, Vodacom which introduced "M-Pesa", in April 2008, the same product which was firstly launched in the world by Safaricom in the Kenyan market in 2007. In 2009, Bharti Airtel received its LNO for the introduction of "Airtel Money", and in 2010 Tigo, was allowed to enter the market with "Tigo Pesa".

Electronic Money Issuer (EMI) Guidelines were issued in 2010 to replace LNO since the Mobile money users were rapidly growing and warranted more close supervision for ensuring safeness and a stable financial system. By 2013, 50 percent of Tanzanian adults were reported that they had used one of the M-money services in the past 12 months as compared to 12 percent in 2010 Mattern and McKay (2018).

M-money is issued by the MNOs whose primary businesses are telecommunication, but by law, for these companies to provide financial services they must operate a subsidiary company Mobile Money Issuer (MMI) that handles the M-money but uses the infrastructure of its main company.

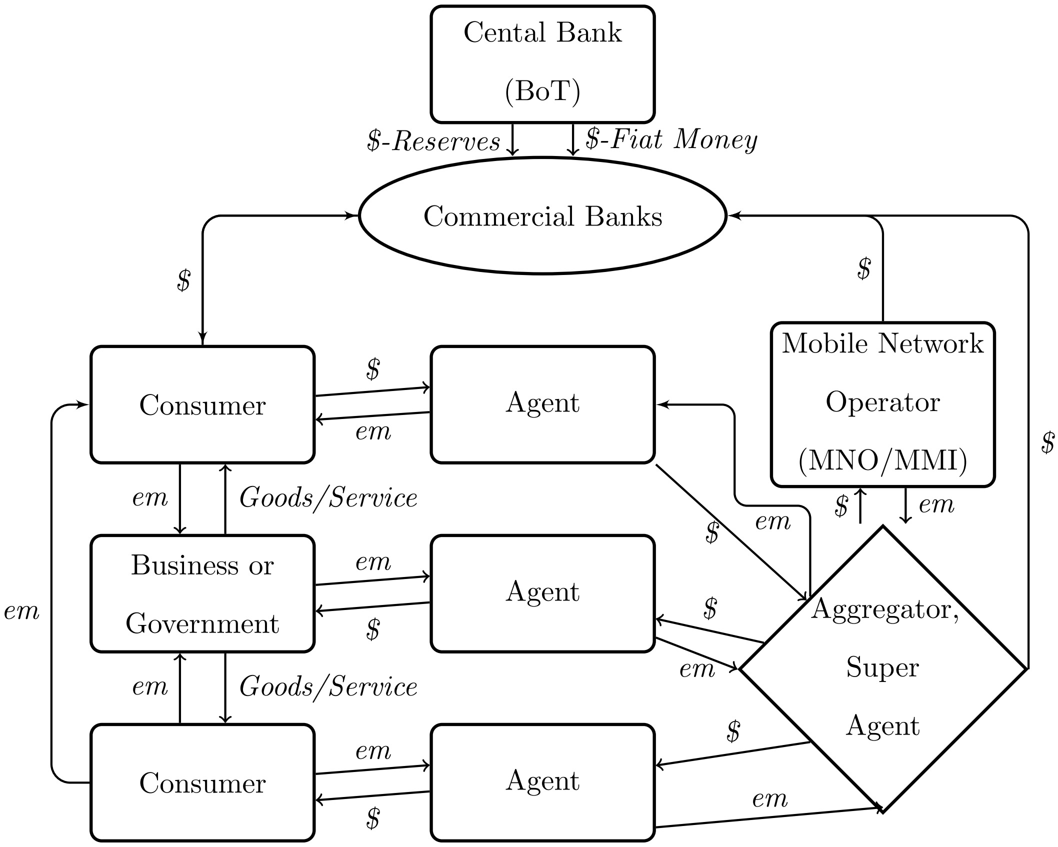

Figure 1.1: Mobile money flow chart

The interaction of different players in the system as shown in Figure 1.1, starts from issuing M-money by MMI by depositing its equivalent in the commercial bank. The e-money is issued in the system and passed to Aggregator/Super agent who helps to manage agents liquidity, then distributed to different agents network to facilitate cash-in and cash-out (CICO) transactions. The consumer can transact person-to-person (P2P), person-to-person (P2B) person-to-person (P2G), and the reversal in exchange of goods and services.

The system is designed in such a way that the total amount of M-money in the system is equal to the amount of deposits in the trust account, which backs up the entire electronic money float.

The account-to-account interoperability between mobile money providers was commenced in 2014, which increased the volume of the transaction as before people could transact with people of the same network only since the mobile number acts as the customers' Mobile money account. In 2017, 60 percent of M-money had used interoperable (P2P) transactions. In the same year, Tigo Pesa becomes the world's first M-money service to offer pass-through interest to wallet holders.

The mobile money model has increased financial inclusion, reduced the cost of transactions, and decreased reliance on cash, Mbiti and Weil (2015). Figure 1.A.3, indicates how the different FinTech products' transaction value in terms of DGP has altered traditional ways of dealing with money. Commercial banks also started agent banking and mobile banking which deepen financial inclusion. In 2015, the Payment Systems Licensing and Approval Regulations were issued and replaced EMI to contain potential risks and operationalization from these developments.

1.3 Monetary Policy Transmission

The monetary transmission mechanism, describes how policy-induced changes in the short-term nominal interest rate, nominal money stock or and bank credit influences the real variables such as aggregate output, investment, Inflation and employment.

Monetary Policy Refers to central bank's reaction function and rules followed to achieve primary objectives of financial and price stability (Tanzania). Other countries includes; full employment and stability of foreign payments.

Monetary Policy Reaction Function Shows how central bank would reset its key policy instruments in response of changing domestic and external macroeconomic environment.

There are various channels of monetary policy transmission mechanisms that impact various markets segment and different macroeconomic variables in a diverse intensities and speeds due to the underlying macroeconomic environment that differ in time and space.

- Interest rate channel

  An expansionary policy given sticky prices results in decline of real interest rates thus increase in aggregate demand inflationary pressures.

- Credit channel

  Decrease the policy rate, leads to fall in debt obligations hence strong balance sheets and lower default risks. In turn, lending increases thus higher economic growth coupled with inflationary pressures.

- Exchange rate channel

  An expansionary policy results lower returns on domestic investment decline relative to foreign thus instigating capital outflows, depreciation, rise in exports and falling imports, which stimulate aggregate demand.

- Asset price channel

  Decrease in policy rate, thus public reallocate savings to non-interest bearing assets (real estate and equity). Thus increase in wealth and firms' market value higher, then higher economic growth consumption.

- Expectations channel

  Changes in M.Policy stance sends signals which influence public expectations on growth and inflation, future income and profits/losses. Such changes in expectations in turn determine private economic activities.

Appendix

Appendix 1.A Observations from Data

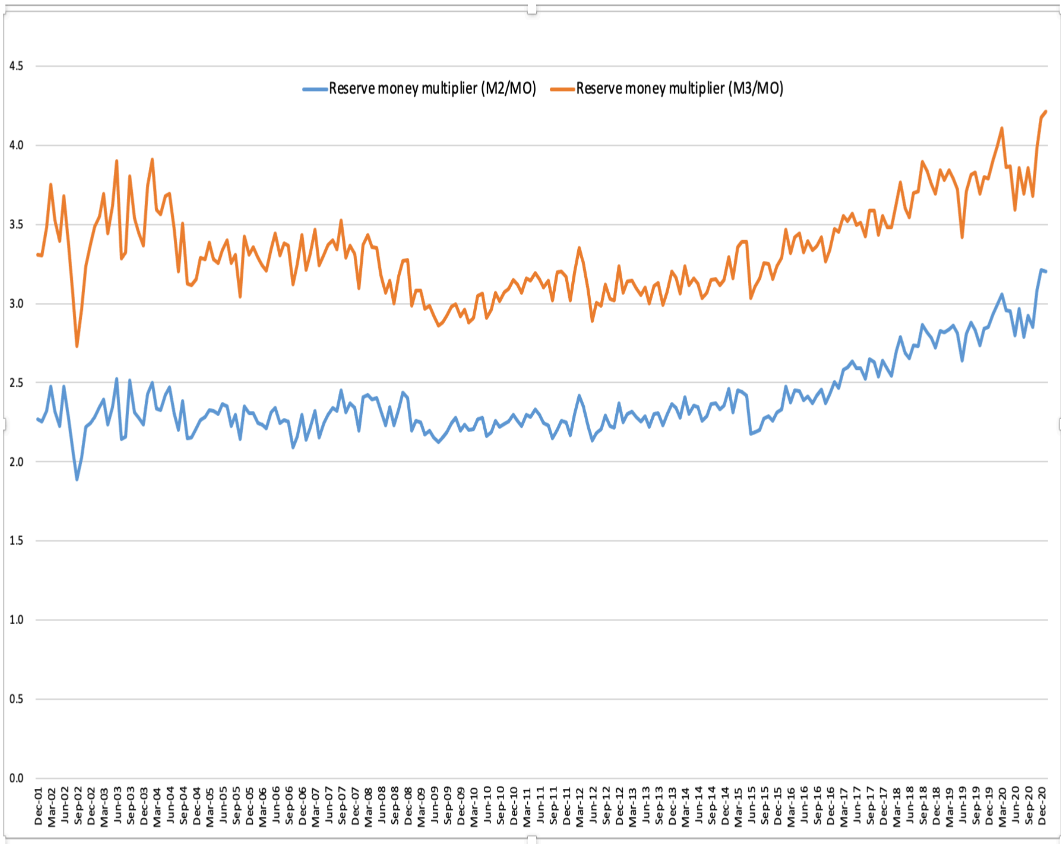

Figure 1.A.1: Money Multiplier

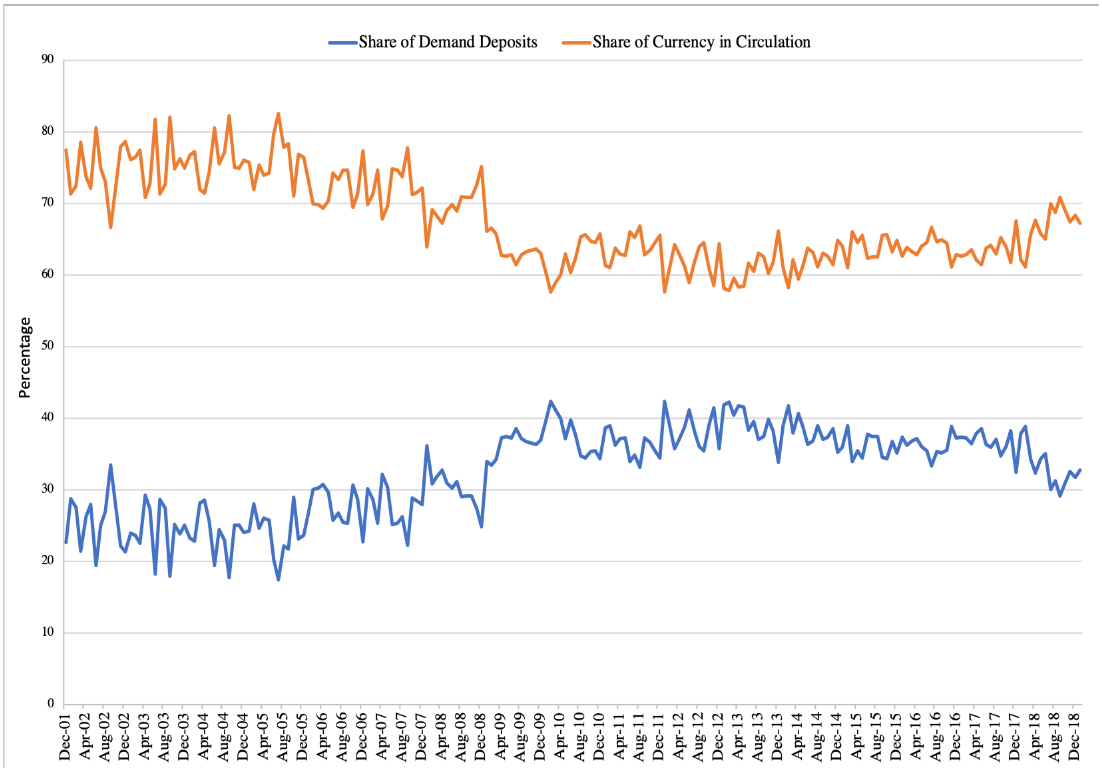

Figure 1.A.2: Share components in M1 money supply

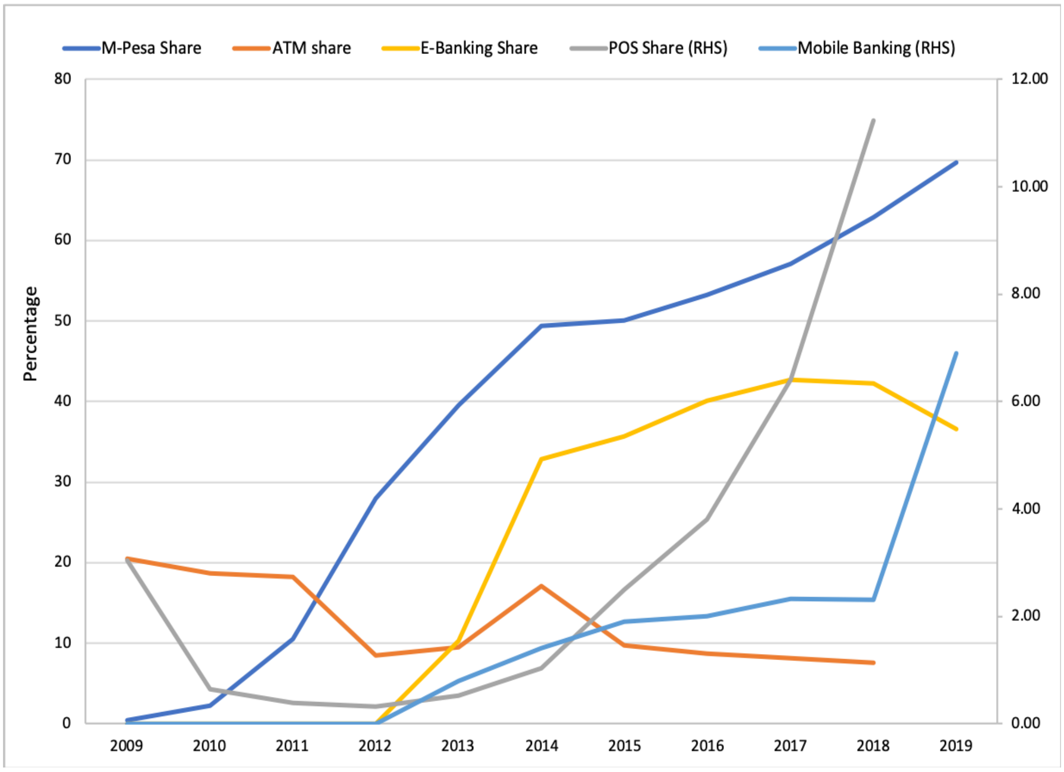

Figure 1.A.3: Transaction value of Fintech products as percentage of GDP

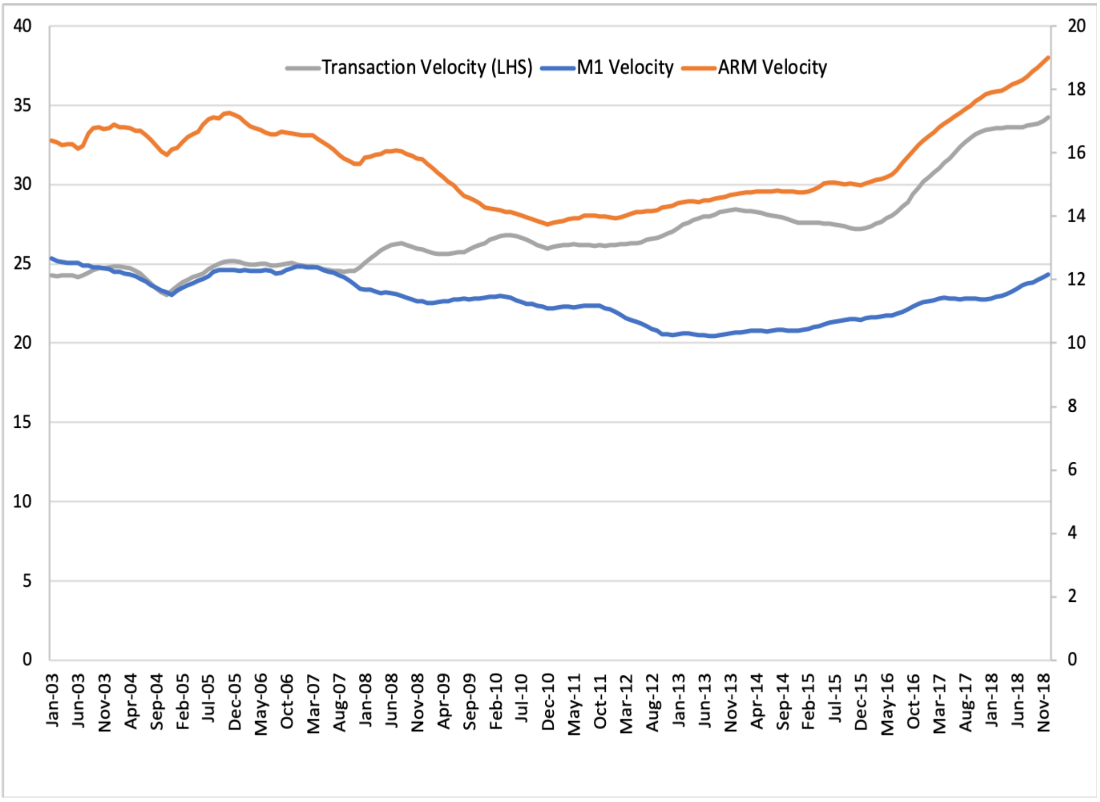

Figure 1.A.4: Money Velocity

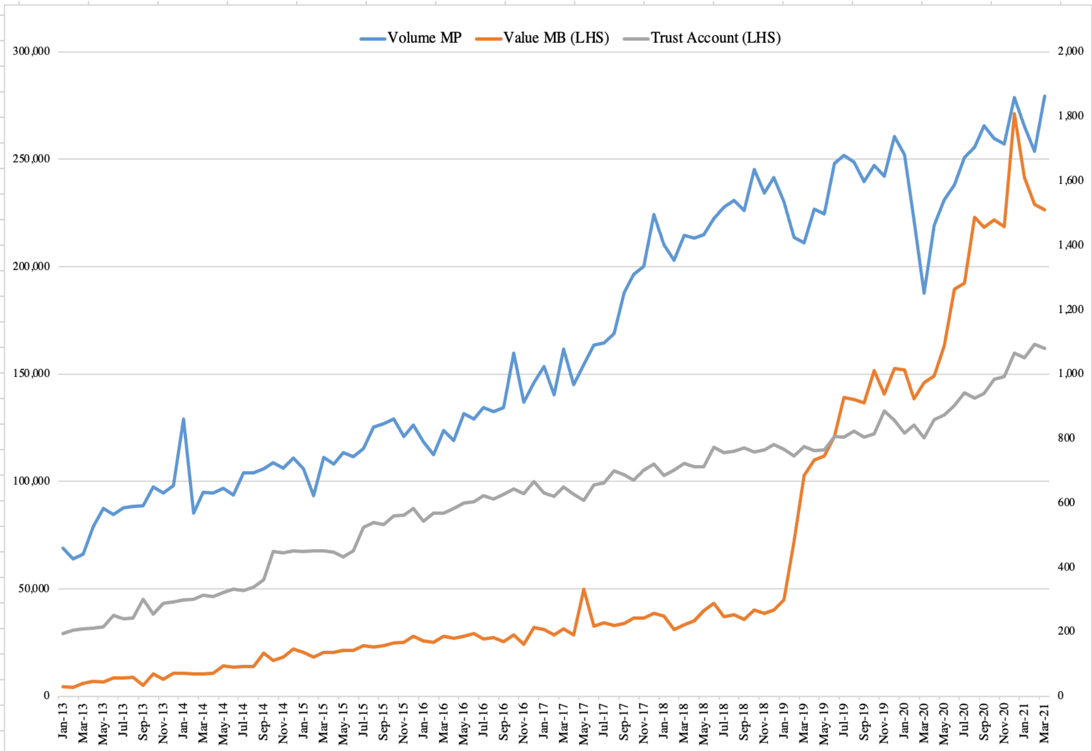

Figure 1.A.5: Mobile Payment and Mobile Banking

Chapter 2

Mobile Money and Monetary Policy Transmission Mechanism in Tanzania: MS-VAR's Stylised Facts.

2.1 Introduction

Vector autoregression models have been used widely to empirically analyze the transmission mechanism. The popularity of this methodology can be traced since when Christopher Sims criticized the restrictions required in large structural macroeconomic models, by proposing an alternative method that treats all variables as being endogenous different from the assumption exogenous dichotomy of the former models.

In VAR, a vector of variables is regressed on their lagged values as well as on the other variables. This gives a convenient way of summarising the dynamic relationships among variables. By employing several tools such as impulse response functions, residuals variance decomposition, and the Granger causality.

Monetary policy effectiveness in delivering its policy objective of price and financial stability largely depends on stability and predictability of money demand especially for countries like Tanzania that use monetary aggregates as a policy tool.

Arrau et al. (1995) enlighten on financial innovation from looking into data as it shows shifts or even continuing movements in holdings of money balances that are unrelated to the behavior of the explanatory variables chosen. And the shifts are nearly always in the direction of firms and households finding ways or being offered means to economize on their holdings of money balances. This tendency has explicitly showed by Mobile money where people tend to hold electronic money as an alternative to currency and demand deposits since it's a cheaper, safe, and convenient way to carry out transactions and settling debts.

To answer this question, we are going to use two approaches, first by splitting the sample into two periods before and after effective use of mobile money and compare their impulse response function as well as forecast error variance decomposition using Structural Vector Autoregressive (SVAR) model. However, the main challenge of this approach it is vulnerable to distortion from a variation of the degree of freedom between the two sub-samples. The second approach that augments the first one is Markov Switching Vector Autoregressive (MS-VAR) model. With this method, the model is computed without any prior knowledge about breakpoint, since the structural break is expressed as Markovian regime shift which is determined by estimation.

2.2 Literature Review

2.2.1 Structural VAR

Vector Autoregressive models for macroeconomic analysis can be traced back from, Sim's (1980) seminal paper "Sims critique" on traditional large macro models that were over-identified, and most economists are not actively engaged in constructing or using them. The traditional approach which identifies changes in monetary policy with changes in the stock of money is not adequate, since the growth rate of monetary aggregates depends on a variety of non-policy factors. In particular, the changes in velocity due to financial innovation deregulation and others factors are impediments to rely on money growth alone as the measure of policy direction Bernanke and Mihov (1998).

The existing literature on monetary policy transmission mechanisms in Tanzania is mostly based on VAR analysis. A number of these empirical works argue that monetary transmission mechanism is more effective in developed economies as compared to developing ones Davoodi et al. (2013), Mishra and Montiel (2013), Buigut (2009) and Yao et al. (2005). The main basis of this argument is mainly less developed financial markets and institutions, adversely affect the proper channel of monetary policy to the real economy as compared with developed economies where their markets are sufficiently deep and liquid. There is insufficient empirical literature on the impacts of financial innovations and structural changes the country experienced on monetary policy, this paper will act towards bridging that information gap.

Montiel et al. (2012) analyzed the effects of monetary policy shocks on aggregate demand in Tanzania. They employed a recursive VAR on monthly data for the period from January 2002 to September 2010. Findings show that reserve money has a statistically significant effect on the price level, but the effect is not economically significant, a very weak monetary policy effect on the exchange rate and monetary policy was found to have no output effects. They also indicated due to the large dominance of the agriculture sector it becomes challenging to properly identify supply and demand shocks. This study was generally unable to provide strong evidence of effective monetary transmission in Tanzania.

Buigut (2009) employed a structural vector autoregression (SVAR) to assess asymmetric behavior between partners states in the East Africa Community (EAC) which could lead to monetary union. Annual data on real output, price level, and short-term interest rate from 1985 to 2005. The overall finding shows the effect of monetary policy shock to be weak and insignificant on output for all EAC member countries. On the other hand, interest rate innovations on the inflation rate in terms of the speed and direction of response are different for the three countries but also insignificant.

Davoodi et al. (2013) used a similar approach by using data for the period from 2000 to 2010. The conclusion was not different from previous studies, that monetary transmission mechanism tends to be generally weak when using standard statistical inferences, but somewhat strong when using non-standard inference methods. However, transmission for Kenya's case was relatively strong in Kenya, from policy shocks to prices as compared to the rest of EAC countries.

Misati et al. (2010) in the case of studies on the effects of FinTech on monetary policy examined the effect of financial innovation that includes FinTech, on monetary policy transmission through interest rate channels in Kenya. The study used Two-Stage Least Squares (2SLS) and the findings show that financial innovation dampens the interest rate channel of the monetary transmission mechanism. Arguing advancements in payment technology might have enabled consumption smoothening and therefore contributed to the weakening of the importance of the interest rate channel in the transmission mechanism.

Nyamongo and Ndirangu (2013) analyzed the effects of financial innovation in the banking sector on the conduct of monetary policy in Kenya during 1998-2012. The study used 5-variable (GDP, CPI, M3, short-term interest rate, and nominal exchange rate) VAR. The findings of this study show different results as compared to the previous ones. The financial innovations that happened in Kenya improved the effectiveness of the monetary policy such that, interest rate shock impacts on GDP within 4 quarters and the effect remains effective until the 9^th quarter. Nevertheless, these innovations have come at a cost in which the velocity of money, the money multiplier, and the money demand have become much more unstable.

2.2.2 Markov Switch-VAR

In the recent past regime-switching models have caught significant attention in analyzing and understanding different monetary policy transmission mechanisms. Especially in the environment which structural changes that alter functional relationships existing among different economic variables. So far there is limited literature on the analysis of monetary policy transmission mechanisms using regime switch methodology in Tanzania. Therefore, this part will focus on general literature on regime switch VAR models in which this concept will be extended to the Tanzanian case.

In assessing the extent of mobile money transformation on the monetary policy transmission mechanism, we are going to use Structural Vector Autoregressive (SVAR) that were pioneered by Sims et al. (1986) and Markov Switch Vector Autoregressive (MSVAR) models. These techniques have become one of the major ways of summarizing and extracting information from macroeconomic data by using the reducing form VAR. Then impose structural restrictions on the equation errors that are taken as the economic shocks to form SVAR to interpret the data for policy analysis.

In identifying monetary policy and allowing for simultaneity and regime switching in coefficients and variances Sims and Zha (2006), used a multivariate model basing on U.S. data from 1959. In this study, they fit the different classes of MS-VAR models and the best fit was the one that allows time variation in structural disturbance variances only. The model that allowed variation in coefficient in different regimes was the one with varying coefficient in monetary policy rule only. The study found main 3 regimes for the U.S. and concluded monetary targeting was central in the early '80s but was also important occasionally in the '70s. The regime changes were not rooted in the rise in inflation in the '70s or its decline in the '80s, but stable monetary policy reactions to a changing array of major disturbances generated the historical pattern.

Valente (2003) also used a Markov-switching VAR model of the central banks' monetary policy reaction functions for the countries in G3 and E3 countries. By using monthly data for the period covering 1979–1997. The models allowed for shifts in the intercepts and variance-covariance matrices. Because evidence shows interest rates are well characterized by a mixture of normal distributions with variation in their variances. The finding shows a significant and persistent shift influencing the dynamics of the central banks' instrument interest rates that are driven mainly by discrete changes in inflation targets. In getting the best fit, the model that allowed for shifts in the variance-covariance proved to be more superior, a similar observation was also made by Sims and Zha (2006).

Rubio-Ramirez et al. (2005) they developed the necessary and sufficient condition for the exact identification of a Markov-switching structural vector autoregression (SVAR) model with the theorem that applies to linear models and nonlinear with restrictions on the structural parameters. Their finding shows, models restricted to only time-varying shock variances dominate the other models since it is assumed in other parameters are not needed for the identification of shocks rather the error covariance matrix. The results showed a persistent post-1993 regime which was associated with low volatility of shocks to output, prices, and interest rates.

Fujiwara et al. (2003) estimated the identified Markov switching vector autoregression model, aiming at checking the existence of structural change without any prior knowledge on the breakpoint and to be able to compare the effect of monetary policy before and after the break. Without splitting the sample, his results showed that there was a structural change in the 1990s and the effect of monetary policy has become weaker since then. This was suggesting that the Japanese economy had changed regime where the conventional monetary transmission mechanism was not fully functioning since interest rates were close to zero thus limited monetary expansion.

Lange (2010) explored a model that identifies monetary policy responses using nonlinear regime-switching, a structural framework that allows for contemporaneous policy reactions to financial disturbances in a small open economy. The finding shows that Canada's monetary policy has gone through different regimes which have been kindled by changes in operating procedures and inflation targets. As for the case of the United States in the early 1970s, Canada changed operating procedures and medium-term inflation targets. Further the results indicate the transmission of policy shocks and responses through financial markets are regime independent. Because of using "hybrid" operating procedure in different monetary policy regimes, where it sets a monetary policy rate, counter-cyclically to smooth exchange-rate fluctuations and dampen unexpected increases in long-term yields.

2.3 Model Description

2.3.1 Structural VAR

We consider $VAR(p)$ model of n dimension with general form form of;

$$Y_t = Z_0 + Z_1 Y_{t-1} + Z_2 Y_{t-2} + \cdots + Z_p Y_{t-p} + B\mu_t, \tag{2.1}$$

$$Y_t = Z Y_{t-1} + B\mu_t \tag{2.2}$$

Where $Y'_{t-1} \equiv (1, Y'_{t-1}, \cdots, Y'_{t-p})$ is of $(np + 1)$ dimensional,

$Z \equiv [Z_0, Z_1, Z_2, \cdots, Z_p]$ is of $n \times (np + 1)$, dimensional and

$\mu_t = (\mu_{1t}, \mu_{2t}, \cdots, \mu_{nt})' \sim (0, \Sigma_\mu)$ is of n dimensional white noise process, that is μ_t is serially uncorrelated with zero mean and covariance matrix Σ_{Z_0} Z_0 is $n \times 1$ fixed vector non-stochastic intercept term.

The $VAR(p)$ process y_t is assumed to be stationary and stable with the polynomial $det(I_n - Z_1 k - Z_2 k - \cdots - Z_p k^p)$ has all of its roots outside the complex unit circle if (2.3.1) has unit roots $k = 1$, some or all of the components of y_t are cointergrated, the assumption here is at most all all variables are integrated of $I(1)$ that means they can be $I(0)$ by first difference or by removing the trend element.

Following Lütkepohl (2005) the $A - B$ model, reduced form VAR in (2.2) can be multiplied by $n \times n$ invertible matrix A, that allows for the instantaneous relations among variables such that;

$$A^{-1}AY_t = A^{-1}ZY_{t-1} + A^{-1}B\mu_t \tag{2.3}$$

$$Y_t = GY_{t-1} + A^{-1}B\mu_t \tag{2.4}$$

The SVAR in (2.4) has structural shocks or innovations ε_t, which are linear combination of μ_t. This approach has been used by Blanchard and Perotti (2002) and Bernanke and Mihov (1998) such that $A\varepsilon_t = B\mu_t = (\varepsilon_{1t}, \varepsilon_2 t, \cdots, \varepsilon_{nt})'$. The ε_t shocks have zero mean, constant variance and have no serial correlation, i.e $E(\varepsilon_{it}\varepsilon_{jt} = 0)$.

The matrix A is assumed has a unit in the main diagonal such that, $\Sigma_\varepsilon = A\Sigma_\mu A' = diag(\sigma_1^2, \cdots, \sigma_n^2)$, therefore $\varepsilon_t \sim (0, \Sigma_\varepsilon)$.

2.3.2 Markov-Switching VAR (MS-VAR)

Markov regime-switching models are the type of nonlinear time series models, that have attracted attention among Economists following Hamilton (1989) who used MS-VAR to model the U.S business cycle. These types of models are important to understand the dynamism in the time series data generating process. Many of the economic time series occasionally exhibit dramatic breaks in their behavior that is associated with events such as abrupt changes in government policy or the financial crises Sims and Zha (2006)

The model portrays the fundamentals of time series structure in different regimes, principled by a switching mechanism that is controlled by an unobservable discrete-state Markov process variable that follows a first-order Markovian chain.

Following, General specification of MS-VAR is given by;

Following Krolzig (1998), General specification of MS-VAR is given by;

$$Y_t = Z_0(s_t) + \sum_{j=1}^{p} Z_j(s_t)Y_{t-j} + B(s_t)\mu_t, \tag{2.5}$$

$$Y_t = G(s_t)Y_{t-1} + A^{-1}B(s_t)\mu_t \tag{2.6}$$

Where μ_t is Gaussian innovation process, $\mu_t \sim NID(0, \Sigma(s_t))$, $Y_t = (Y_{1t}, \cdots, Y'_{Kt})$, $t = 1, \cdots, T$ and the parameters of VAR process depends on unobservable state variable s_t, which represents a particular regime or state of the world, with $s_t \in \{1, \cdots, M\}$, where M represents possible number of states.

MS-VAR has different classes of models depending which parameters are switching. Parameters in (2.5), $Z_0(s_t)$, $Z_j(s_t)$ and $\Sigma(s_t)$ are all assumed to be switching. In its most general form, the model is termed as MSx(M)-VAR(p), of which x indicates parameters that are regime dependent M is the number of regimes and p number of lags.

$MSI(M) - VAR(p)$; A model which its intercept is regime dependent,
$MSA(M) - VAR(p)$; A model with varying coefficients $(A_j(s_t))$ across regimes,
$MSH(M) - VAR(p)$; A model with with regime dependent error-covaraince $(\Sigma(s_t))$
$MSIAH(M) - VAR(p)$; A model which all of its parameters are regime dependent
$MSM(M) - VAR(p)$ The mean adjusted model.

$$Y_t - Z_0(s_t) = \sum_{j=1}^{p} Z_j(Y_{t-j} - B\mu(s_t)) + B\mu_t, \tag{2.7}$$

The main difference between models in (2.7) and (2.5) is that, means of the time series jump in MSM-VAR immediately to their new levels after a regime change while MSI-VAR their means approach new level smoothly, Krolzig (1998). In case intercept is regime dependent, y_t can be modeled by z_t with the following Autoregressive specification;

$$z_t = \begin{cases} \alpha_0 + \beta z_{t-1} + \varepsilon_t, & s_t = 1 \\ \alpha_1 + \beta z_{t-1} + \varepsilon_t, & s_t = 2, \end{cases} \tag{2.8}$$

The specification in (2.8) is assumed to be stationary process. The mean of the AR(1) switches between $\frac{\alpha_0}{1-\beta}$ when $s_t = 1$ and $\frac{\alpha_1}{1-\beta}$ when s_t changes from 1 to 2. The variable z_t is governed by two distributions or regimes with distinct means and the switch between regimes is determined by s_t. In this case the model has one structural change Kuan (2002). The most general description of the of random variable z_t using (2.8) is given by

$$z_t = \alpha_{st} + \beta z_{t-1} + \varepsilon_t \tag{2.9}$$

Where $s_t = 1$ for $t = 2, \cdots, \tau_0$ and $s_t = 1$ for $t = \tau 0 + 1, \cdots, T,$.

The probability law governing the observed data will necessarily require a probabilistic model which accommodates the changes in s_t, that can be shown as;

$$p_{ij} = Pr(s_{t+1} = j | s_t = i, y_{t-1}, y_{t-2}, \cdots), \qquad \sum_{j=1}^{2} p_{ij} = 1 \qquad \forall_{i,j} \in \{1, 2\} \tag{2.10}$$

Where p_{ij} is the probability of switching from regime j in time t to regime i in $t + 1$. The the transition probabilities in P is characterized by p_{11}, which shows probability of switching to regime 1 next period given existence of regime 1 currently p_{12}, shows probability of switching to regime 2 next period given existence of regime 1 currently and vise versa for p_{21}.

$$\begin{aligned} P &= \begin{bmatrix} Pr(s_{t+1} = 1 | s_t = 1) = q & Pr(s_{t+1} = 2 | s_t = 1) = 1 - q \\ Pr(s_{t+1} = 1 | s_t = 2) = 1 - p & Pr(s_{t+1} = 2 | s_t = 2) = p \end{bmatrix}, \\ &= \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \end{aligned} \tag{2.11}$$

Furthermore, each regime should be sufficiently long-lasting, as opposed to frequently changing, to allow for investigation of the existence of structural breaks. Therefore, the model should be kept as parsimonious as possible Fujiwara (2006).

Since s_t is unobservable, it can however be inferred through the observed behavior of Y_t. The parameters necessary to fully describe the probability law governing Y_t, are; variance of the white noise σ_ϵ^2, the autoregressive coefficient β, the two intercepts α_0 and α_1, and the two-state transition probabilities, p_{11} and p_{22} Hamilton (2016).

2.3.3 Data and Identification

The firstly SVAR analysis is based on four variables namely Index of Industrial Production (IIP), consumer price index (INFL), broad money supply (M2), and Average Reserve Money (ARM). The estimations are performed by splitting the entire sample data into two subsamples.

First sample; 1998M01-2008M06;[1] which were transformed from level form to natural logarithm then seasonally adjusted, and differenced to obtain stationary data series. This is regime defined as before, indicating time before the introduction of M-money. Second sample; 2008M06-2018M12; this is regime defined as after indicating a time after the introduction of M-money.

Identification is an essential part of SVAR models, the popular approach to identify the system for contemporaneous relationships between macroeconomic variables, is the recursive identification Christiano et al. (1996), the non-recursive approach of Gordon and Leeper (1994) and currently number are using sign restrictions.

The identification of monetary policy effects on this paper employed the standard procedures commonly used in most empirical works. Following the recursive identification, Christiano et al. (1999), theoretically GDP and prices are unlikely to

[1]Data source is from Bank of Tanzania (BoT) and National Bureau of Statistics (NBS)

react simultaneously to monetary policy shocks. Under Calvo (1983) sticky prices, prices are changed exogenously at random intervals. Thus, prices do not react contemporaneously to shocks from monetary policy actions.

Bank of Tanzania sets its monetary operational target, Average Reserves by observing and reacting to the current value of GDP growth, inflation, and Money supply(M2). Given the objective of the monetary authority of price stability, it sets the growth of reserves based on the current price level, this ordering implies policy actions affect real variables with lags Bernanke and Blinder (1992).

From 2.4, restrictions are imposed on A and B based on economics to recover the structural parameter and shocks using reduced form estimations.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} \mu_t^y \\ \mu_t^\pi \\ \mu_t^m \\ \mu_t^r \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \epsilon_t^y \\ \epsilon_t^\pi \\ \epsilon_t^m \\ \epsilon_t^r \end{bmatrix} \tag{2.12}$$

In regime-switching VAR volatility in policy shock was included as regime-switching because the data for the growth of Reserves shows two distinct periods of high and low volatility. In the literature, high volatility especially when is not time for economic recession is associated with less effective monetary policy Aastveit et al. (2013) and Castelnuovo and Pellegrino (2018).

The volatility of reserve is highly associated with volatility in short-term interest rates which can easily shamble the policy signal and impedes its transmission mechanism Maehle (2014). Also, some theories explaining "the Great Moderation", pinpoints that structural changes coupled with improved performance of macroeconomic policies, particularly monetary policy are closely linked with a long period of macroeconomic stability.

Regime switching VAR model which will be estimated follows Sims and Zha (2006), but the difference is that, we allow switching only in Monetary Policy parameters and error-covariance matrix for models $MSA(M) - VAR(p)$ and $MSH(M) - VAR(p)$ respectively.

From (2.6) hybrid model in its companion matrix form has three variables; IIP(Y_t), INFL(Π_t), and ARM(R_t). For a parsimonious reason due to the limited number of observations and reduction the number of the parameter to be estimated under the regime-switching framework.

$$\begin{bmatrix} Y_t \\ \Pi_t \\ R_t \end{bmatrix} = A^{-1} \begin{bmatrix} g_{11} & g_{12} & g_{13,st} \\ g_{21} & g_{22} & g_{23,st} \\ g_{31} & g_{32} & g_{33,st} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ \Pi_{t-1} \\ R_{t-1} \end{bmatrix} + A^{-1} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \epsilon_{yt} \\ \epsilon_{\pi t} \\ \epsilon_{rt,st} \end{bmatrix} \tag{2.13}$$

Lag selection, stability and unit root

Using Akaike information criteria (AIC) in Figures: 2.A.2 and 2.A.2, the appropriate lag chosen is 2 . For the case of stationarity, Figure: 2.A.5, shows ADF stationarity test that confirm stationarity of the first-differenced time series, since the null hypothesis of the unit root is rejected at the 5 percent significance level. The stability of VAR model is ensured by checking roots of characteristic polynomial lies inside the unit cycle ref Figure: 2.A.5.

2.4 Empirical Results

This section discusses the model dynamics by looking at impulse responses functions within the estimated structural systems results for both SVAR Models sub-samples and MS-VAR Model.

2.4.1 Regime Switch VAR

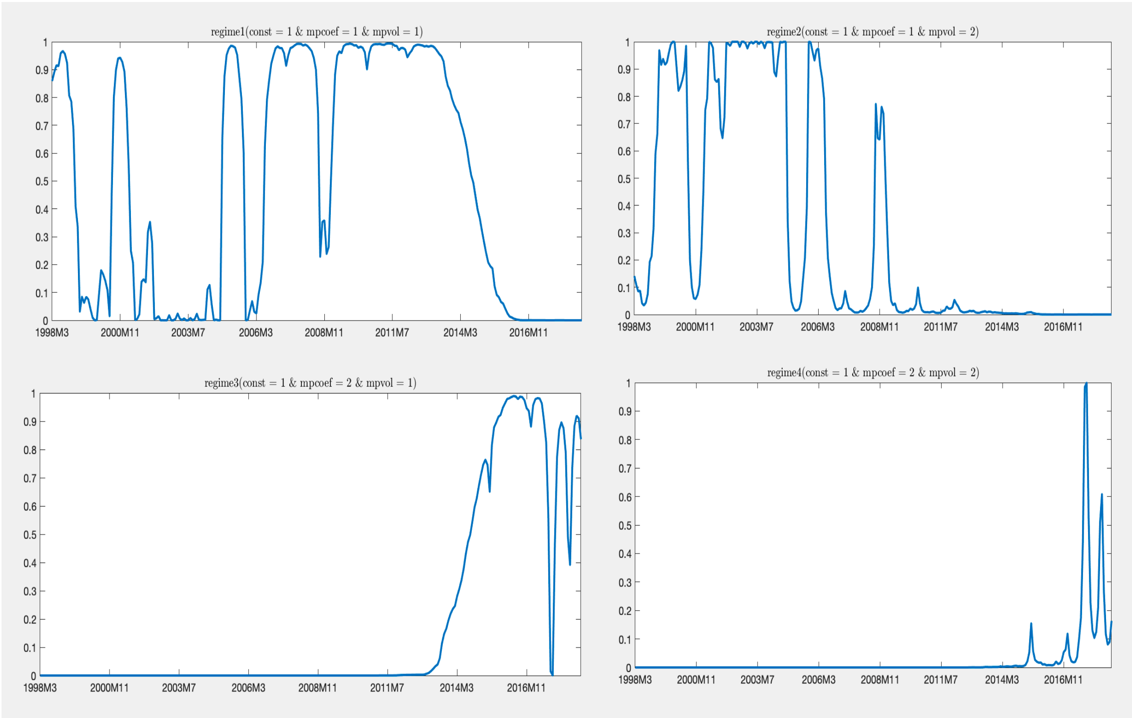

Figure 2.1: Smoothed regime transition probabilities

The empirical evidence from regime-switching VAR, using Tanzania monthly data from 1998 to 2018, suggests that there is a regime shift in monetary policy conduct. The VAR results indicate law of motion underlying the economy has changed of which the changes can be associated with several factors including the introduction of mobile.

Monetary policy regime switched in 2013, consistent with development observed from data in terms of some users of FinTech products, refer Figure: 2.1. Mobile money was initially introduced in the market in 2007 but later it gained momentum as many were adopting it.

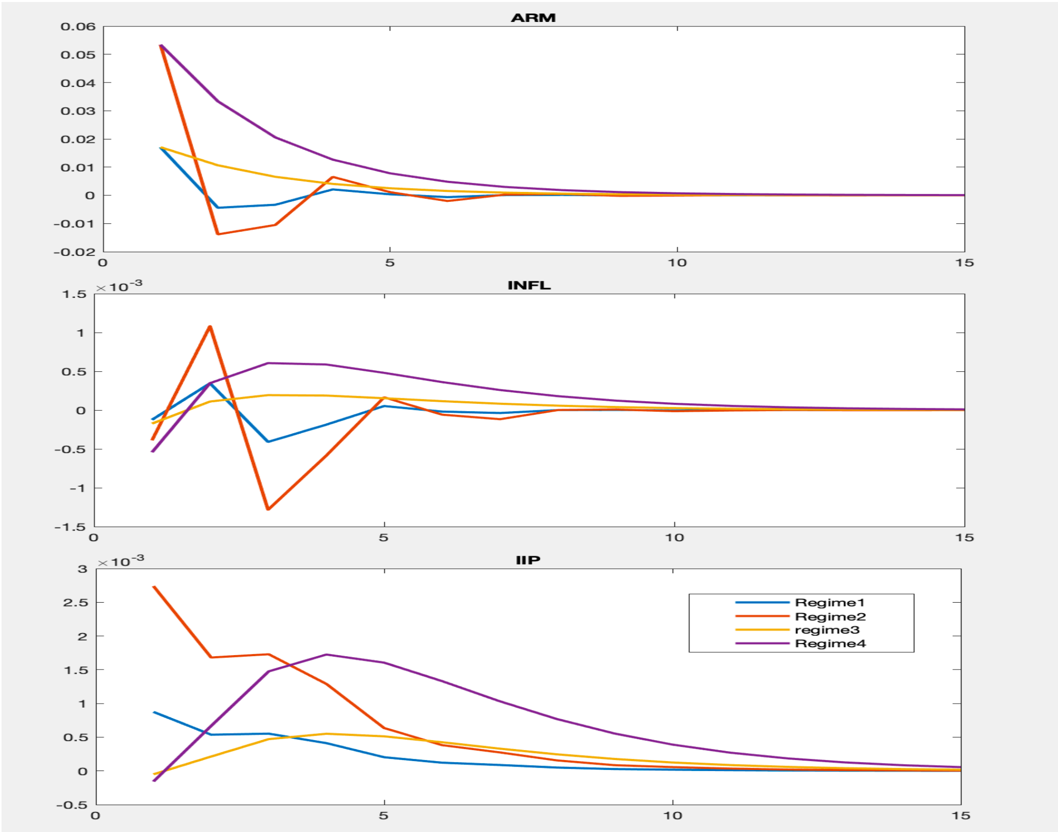

Figure 2.2: Regimes specific impulse response functions to Reserves innovation

The impulse response function in Figure 2.2, shows that the first regime, before mobile (Regime2 and Regime4) is marked by high volatility, inflation, monetary base, and Industrial Production index, which could be due to weak inter-linkage between the monetary policy actions and the real sector, since during this regime majority of people were still using informal financial services and excluded from mainstream services which have direct interaction with policy action.

Unlike the second regime, after mobile money (Regime1 and Regime3) which is marked by a massive increase in the use of mobile money which has to lead to a decrease in transaction cost, increase in velocity and financial inclusion. The first regime's limited inter-linkage between the financial and real sector leads to larger responses for inflation, output, and reserve money because central bank policy actions cannot adjust fully to dampen the impact of the innovations.

2.4.2 Structural VAR

The estimated Structural VAR model of the first period sub-samples Before M-Money in (2008), shows output and inflation had weaker response to policy action and there is disconnect of intermediate target and operational target.

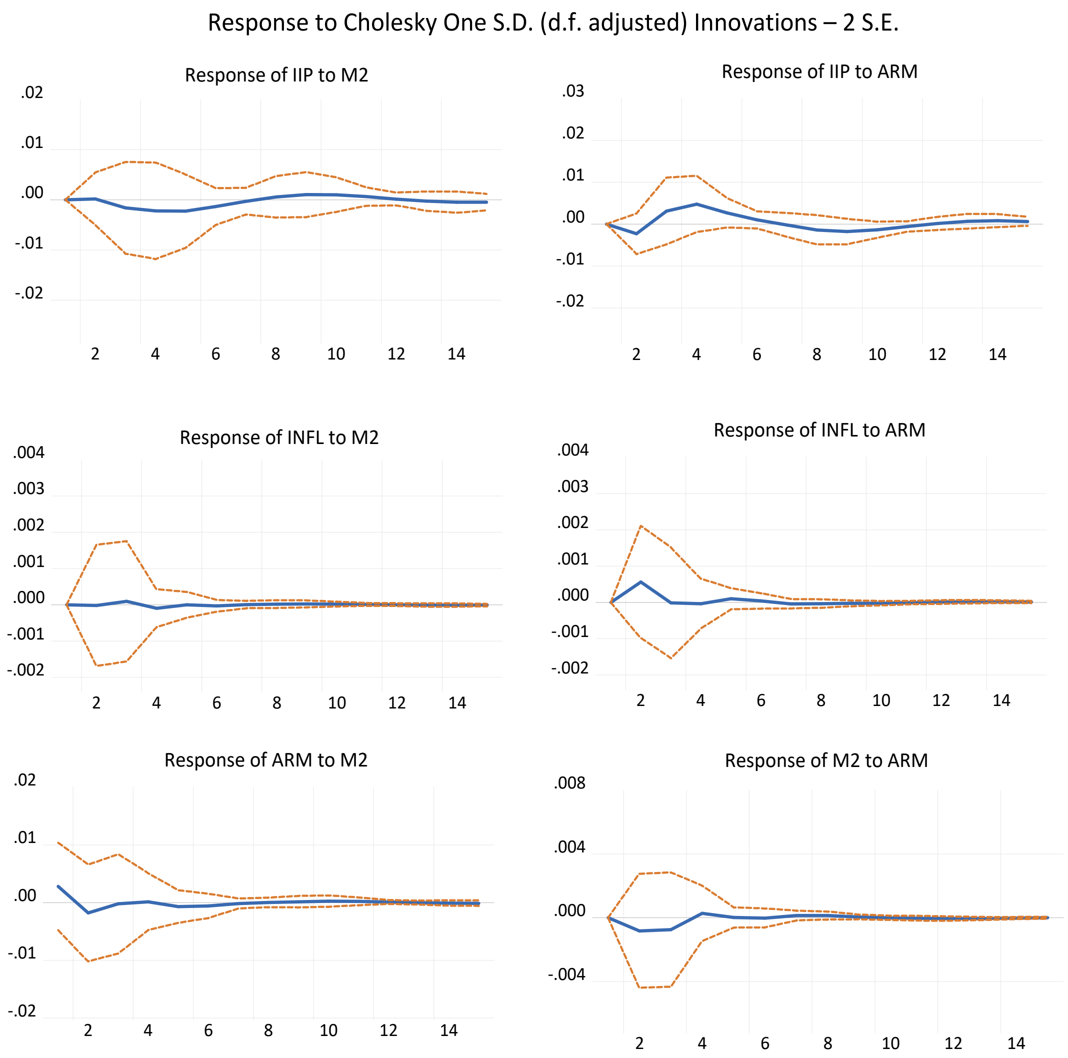

Figure 2.3: Impulse response function Before Mobile Money

The second period is marked by adoption of mobile money and increase in financial inclusion. Results shows output and inflation have relatively strong response to policy action and there is improvement and stable interlinkage of average reserves and money supply(M2).

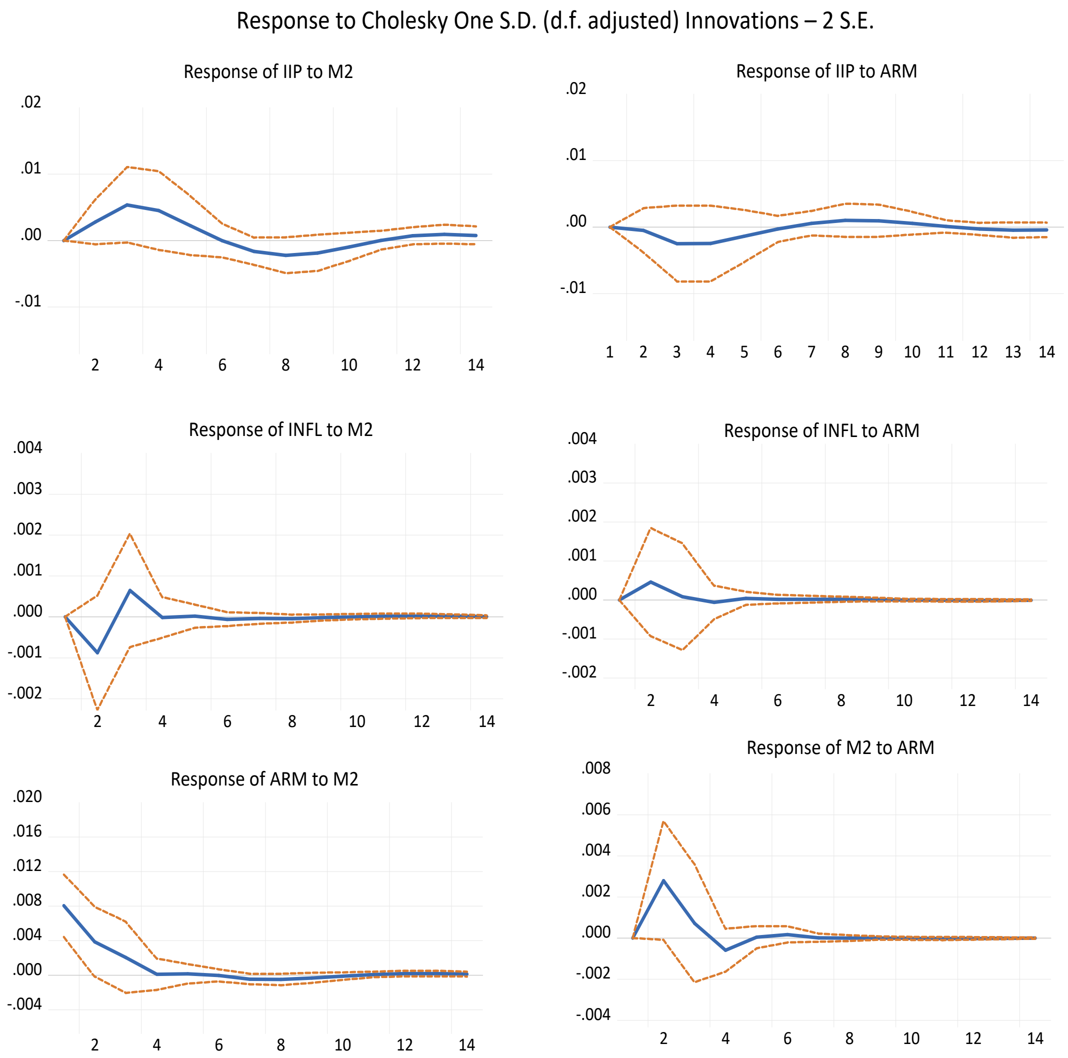

Figure 2.4: Impulse response function After Mobile Money

2.5 Conclusion

This paper addresses the empirical gap by examining the effect of FinTech, particularly mobile money on monetary policy. The study used monthly data from 1998-2018, by exploiting recursive structural and regime switch VAR. From the analysis evidence shows, general existence of a weak monetary transmission mechanism in Tanzania especially when the sample is split. This suggests fitting a constant parameter model to identify the effectiveness of monetary policy is challenging.

Despite the weak Monetary policy transmission mechanism in Tanzania, the regime-switching model does show some differences of slightly improving transmission mechanisms. The time of switching coincides with the period marked many people start using different FinTech products, the effectiveness of monetary policy can then be associated with these financial innovations.

Because of the identification problem of VAR models, this subject will be further be expanded and explored by using more structural models, which are Dynamic Stochastic General Equilibrium models(DSGE).

Appendix

Appendix 2.A Figures and Tables

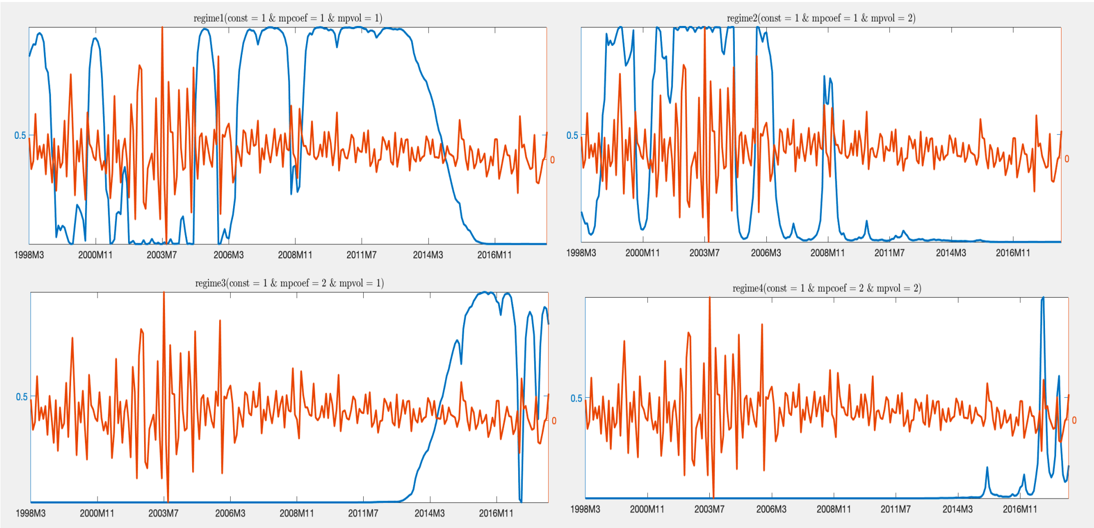

Figure 2.A.1: Smoothed regimes probability against reserves

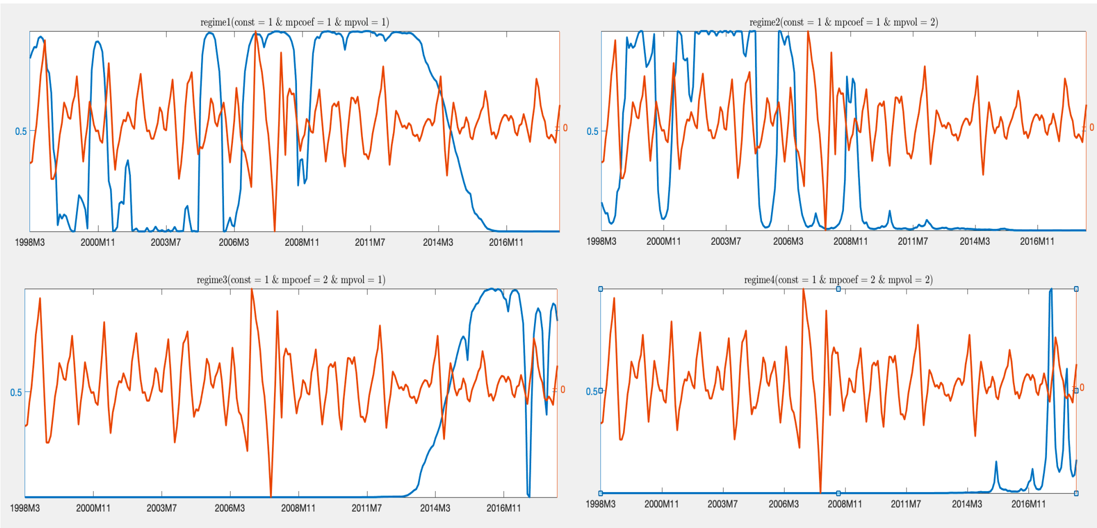

Figure 2.A.2: Smoothed regimes probability against output

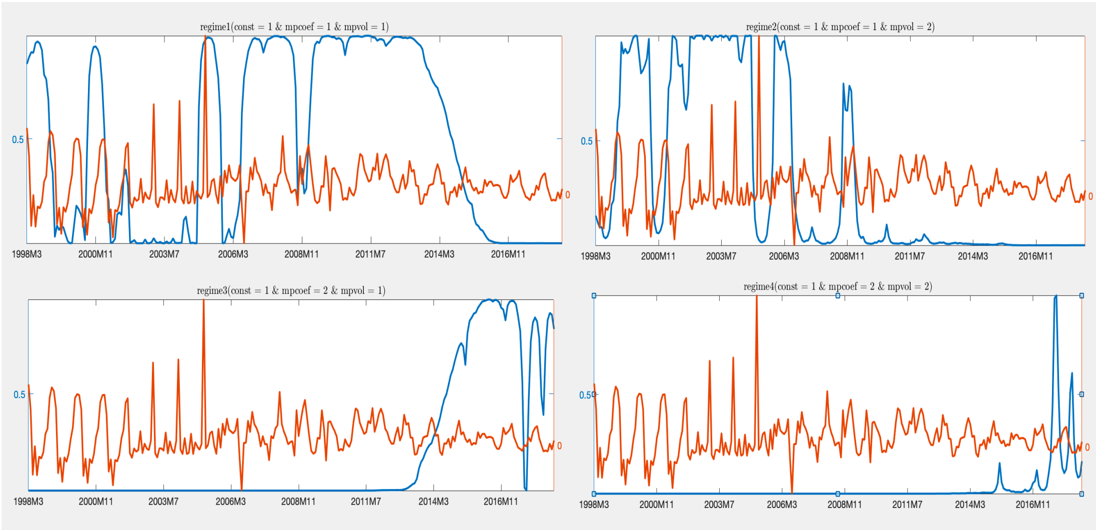

Figure 2.A.3: Smoothed regimes probability against inflation

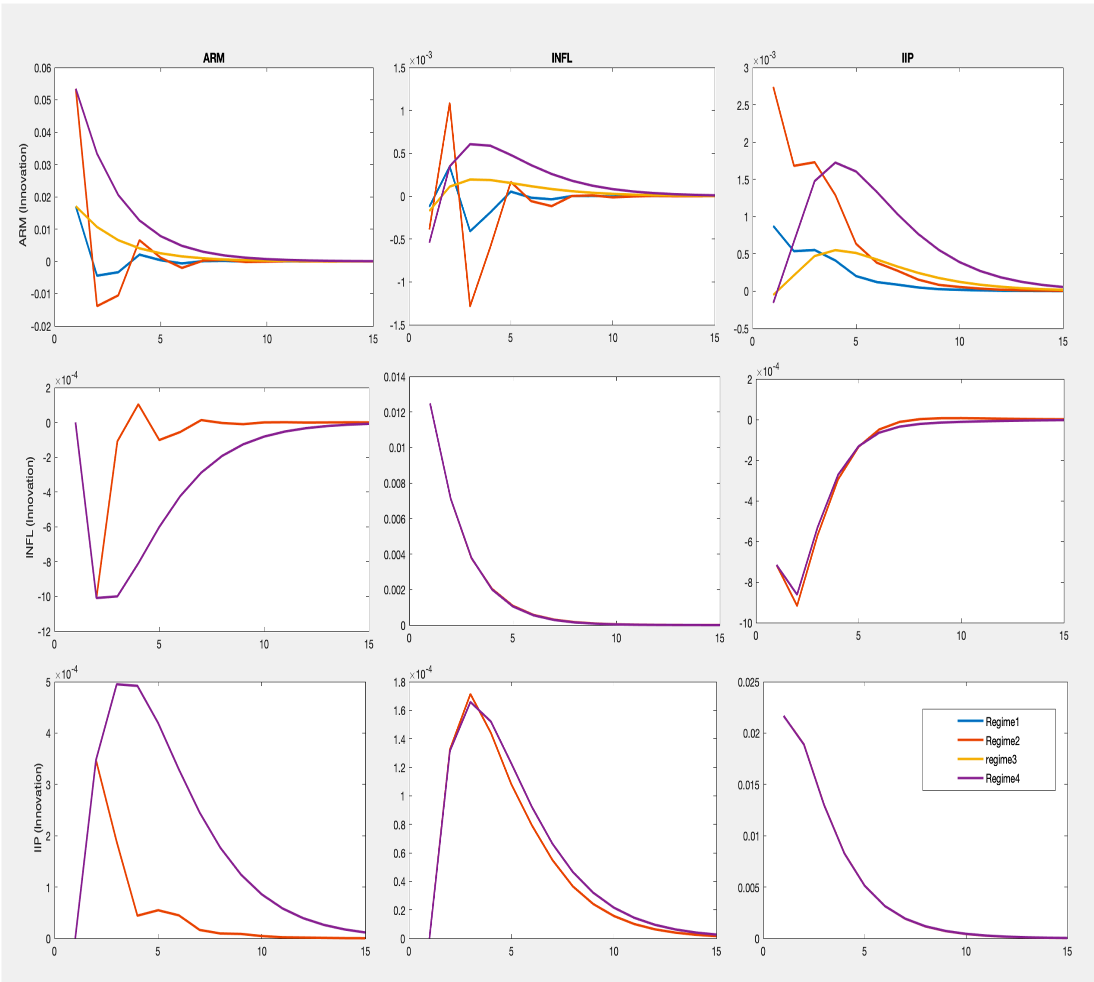

Figure 2.A.4: Regimes specific impulse response function

Sample: 1998M01 2018M12

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1847.586	NA	8.80e-11	-14.63957	-14.59756	-14.62267
1	1942.473	186.7610	4.45e-11	-15.32121	-15.15314	-15.25359
2	2022.327	155.2718	2.54e-11*	-15.88355*	-15.58943*	-15.76520*
3	2025.099	5.324735	2.67e-11	-15.83412	-15.41395	-15.66505
4	2029.180	7.739545	2.77e-11	-15.79508	-15.24885	-15.57529
5	2042.992	25.87119	2.67e-11	-15.83327	-15.16100	-15.56276
6	2056.737	25.41747*	2.57e-11	-15.87093	-15.07261	-15.54970
7	2063.200	11.79648	2.63e-11	-15.85079	-14.92642	-15.47884

* 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

Table 2.A.1: MS-VAR; Lag Order Selection Criteria.

Sample: 1998M01 2008M06

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1546.065	NA	1.64e-17	-24.46135	-24.34880	-24.41562
1	1606.235	114.6092	9.37e-18	-25.01960	-24.34429	-24.74524
2	1667.042	110.9978	5.32e-18*	-25.58797*	-24.34991*	-25.08499*
3	1678.353	19.74948	6.64e-18	-25.37069	-23.56987	-24.63907
4	1698.953	34.33266	7.19e-18	-25.30084	-22.93727	-24.34060
5	1716.288	27.51547	8.23e-18	-25.17917	-22.25285	-23.99030
6	1741.363	37.81236	8.40e-18	-25.18037	-21.69129	-23.76287
7	1757.943	23.68515	9.90e-18	-25.04671	-20.99488	-23.40058
8	1792.185	46.20004*	8.90e-18	-25.19342	-20.57883	-23.31865

* indicates lag order selected by the criterion

Table 2.A.2: Before; VAR Lag Order Selection Criteria

Sample: 2008M07 2018M12

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1786.012	NA	3.63e-19	-28.27003	-28.15748	-28.22430
1	1850.897	123.5908	1.93e-19	-28.90313	-28.22782*	-28.62877
2	1897.625	85.29733*	1.37e-19*	-29.24802*	-28.00996	-28.74503*
3	1915.918	31.93944	1.53e-19	-29.14155	-27.34074	-28.40994
4	1931.181	25.43810	1.80e-19	-28.98699	-26.62342	-28.02675
5	1947.206	25.43771	2.11e-19	-28.84454	-25.91822	-27.65567
6	1965.003	26.83614	2.41e-19	-28.73020	-25.24113	-27.31270
7	1990.347	36.20578	2.47e-19	-28.73567	-24.68383	-27.08953

* indicates lag order selected by the criterion

Table 2.A.3: After; VAR Lag Order Selection Criteria

Before M-Money (SVAR)		After M-Money (SVAR)	
Roots of Characteristic Polynomial Lag specification: 1 2		Roots of Characteristic Polynomial Lag specification: 1 2	
Root	Modulus	Root	Modulus
0.579870 - 0.517317i	0.777088	0.570358 - 0.559190i	0.798751
0.579870 + 0.517317i	0.777088	0.570358 + 0.559190i	0.798751
-0.112304 - 0.636326i	0.646160	0.460289	0.460289
-0.112304 + 0.636326i	0.646160	-0.417116	0.417116
0.273390 - 0.223666i	0.353226	-0.117831 + 0.292193i	0.315057
0.273390 + 0.223666i	0.353226	-0.30842	0.308420
-0.307399	0.307399	-0.021525 - 0.278316i	0.279148
0.155493	0.155493	-0.021525 + 0.278316i	0.279148
No root lies outside the unit circle. VAR satisfies the stability condition.		No root lies outside the unit circle. VAR satisfies the stability condition.	

MS-VAR	
Roots of Characteristic Polynomial Lag specification: 1 2	
Root	Modulus
0.579225 - 0.531418i	0.786070
0.579225 + 0.531418i	0.786070
-0.093920 - 0.526227i	0.534543
-0.093920 + 0.526227i	0.534543
-0.373437	0.373437
0.236328	0.236328
No root lies outside the unit circle. VAR satisfies the stability condition.	

Table 2.A.4: VAR Models stability test

		Constant			
	T-Statistic	***IIP***	***INFL***	***M2***	***ARM***
Level	***1%***	-3.454	-3.454	-3.453	-3.454
	5%	-2.872	-2.872	-2.871	-2.872
	10%	-2.572	-2.572	-2.572	-2.572
	ADF	-0.124	-2.905	-1.442	-1.317
	Prob.*	0.944	0.0461	0.5614	0.6223
		Constant and trend			
	1%	-3.991	-3.992	-3.990	-3.992
	5%	-3.426	-3.426	-3.426	-3.426
	10%	-3.136	-3.136	-3.136	-3.136
	ADF	-2.160	-2.756	0.219	0.364
	Prob.*	0.5097	0.2153	0.998	0.999
		None			
	1%	-2.573	-2.573	-2.573	-2.573
	5%	-1.942	-1.942	-1.942	-1.942
	10%	-1.616	-1.616	-1.616	-1.616
	ADF	4.446	-3.031	12.331	7.173
	Prob.*	1.000	0.003	1.000	1.000
		None			
I(1)	***1%***	-2.573	-2.573	-2.573	-2.573
	5%	-1.942	-1.942	-1.942	-1.942
	10%	-1.616	-1.616	-1.616	-1.616
	ADF	-5.458	-10.572	-7.600	-9.139
	Prob.*	0.000	0.000	0.000	0.000

Table 2.A.5: Unit root test

Before						After					
Variance Decomposition of IIP:						Variance Decomposition of IIP:					
Period	S.E.	IIP	INFL	M2	ARM	Period	S.E.	IIP	INFL	M2	ARM
1	0.02	100.00	0.00	0.00	0.00	1	0.01	100.00	0.00	0.00	0.00
2	0.04	99.58	0.14	0.26	0.03	2	0.02	99.00	0.64	0.35	0.01
3	0.04	98.94	0.21	0.75	0.10	3	0.02	98.40	1.22	0.29	0.09
4	0.04	98.23	0.50	1.00	0.27	4	0.02	97.93	1.52	0.39	0.16
5	0.04	98.05	0.68	0.98	0.29	5	0.02	97.90	1.45	0.48	0.17
6	0.04	98.10	0.67	0.95	0.28	6	0.02	97.96	1.40	0.48	0.16
7	0.04	98.08	0.66	0.99	0.28	7	0.02	97.90	1.47	0.47	0.17
8	0.04	98.01	0.69	1.02	0.29	8	0.02	97.83	1.51	0.48	0.18
9	0.04	97.98	0.71	1.02	0.29	9	0.02	97.82	1.50	0.49	0.18
10	0.04	97.98	0.71	1.01	0.29	10	0.02	97.83	1.50	0.49	0.18
Variance Decomposition of INFL:						Variance Decomposition of INFL:					
Period	S.E.	IIP	INFL	M2	ARM	Period	S.E.	IIP	INFL	M2	ARM
1	0.01	0.09	99.91	0.00	0.00	1	0.01	0.24	99.76	0.00	0.00
2	0.01	0.13	98.90	0.05	0.92	2	0.01	2.20	97.23	0.05	0.51
3	0.01	0.32	98.61	0.16	0.91	3	0.01	3.19	95.85	0.27	0.69
4	0.01	0.38	98.27	0.17	1.17	4	0.01	3.24	95.70	0.34	0.73
5	0.01	0.39	98.25	0.18	1.19	5	0.01	3.37	95.54	0.36	0.73
6	0.01	0.40	98.21	0.18	1.21	6	0.01	3.71	95.20	0.36	0.73
7	0.01	0.41	98.18	0.18	1.23	7	0.01	3.89	95.02	0.36	0.73
8	0.01	0.42	98.17	0.18	1.23	8	0.01	3.90	95.00	0.36	0.73
9	0.01	0.42	98.17	0.18	1.23	9	0.01	3.92	94.99	0.36	0.73
10	0.01	0.42	98.17	0.18	1.23	10	0.01	3.97	94.93	0.36	0.73
Variance Decomposition of M2:						Variance Decomposition of M2:					
Period	S.E.	IIP	INFL	M2	ARM	Period	S.E.	IIP	INFL	M2	ARM
1	0.02	0.20	3.18	96.62	0.00	1	0.02	0.17	3.07	96.76	0.00
2	0.02	1.13	3.24	95.08	0.55	2	0.02	0.17	3.06	95.36	1.40
3	0.02	1.36	3.25	94.72	0.68	3	0.02	0.30	4.46	93.84	1.40
4	0.02	1.36	3.31	94.41	0.92	4	0.02	0.56	4.48	93.56	1.40
5	0.02	1.40	3.31	94.36	0.92	5	0.02	0.63	4.48	93.48	1.41
6	0.02	1.47	3.32	94.24	0.97	6	0.02	0.63	4.48	93.48	1.41
7	0.02	1.51	3.32	94.19	0.98	7	0.02	0.67	4.48	93.44	1.41
8	0.02	1.52	3.32	94.18	0.99	8	0.02	0.71	4.48	93.40	1.41
9	0.02	1.52	3.32	94.17	0.99	9	0.02	0.72	4.48	93.39	1.41
10	0.02	1.53	3.32	94.16	0.99	10	0.02	0.72	4.48	93.39	1.41
Variance Decomposition of ARM:						Variance Decomposition of ARM:					
Period	S.E.	IIP	INFL	M2	ARM	Period	S.E.	IIP	INFL	M2	ARM
1	0.04	1.56	0.21	11.83	86.40	1	0.02	1.49	0.01	25.48	73.03
2	0.04	1.44	0.50	10.95	87.11	2	0.02	1.42	3.63	25.09	69.86
3	0.05	1.48	1.80	10.84	85.88	3	0.02	1.49	3.70	25.04	69.76
4	0.05	1.70	2.19	10.37	85.74	4	0.02	1.54	3.75	25.01	69.69
5	0.05	1.70	2.23	10.49	85.58	5	0.02	1.55	3.79	25.00	69.66
6	0.05	1.76	2.40	10.39	85.45	6	0.02	1.55	3.80	25.00	69.65
7	0.05	1.77	2.40	10.40	85.43	7	0.02	1.56	3.80	25.00	69.65
8	0.05	1.78	2.43	10.39	85.40	8	0.02	1.57	3.80	25.00	69.64
9	0.05	1.78	2.43	10.39	85.41	9	0.02	1.57	3.80	25.00	69.64
10	0.05	1.78	2.43	10.39	85.40	10	0.02	1.57	3.80	25.00	69.64

Table 2.A.6: Variance Decomposition

Chapter 3

A DSGE Model for Assessing Financial Technology Impacts on Effectiveness of Monetary Policy in Tanzania

3.1 Introduction

Monetary policy transmission mechanism has been changing over time throughout the world depending on the changes in the underlying structure of the economy. The changes can be due to several factors including, development in the payment systems, changes in private consumption behavior, and degree of integration of households in the financial systems.

The effectiveness of monetary policy depends on how well the financial structure is interlinked with the macroeconomic environment. The use of technology has proved to largely influence this inter-linkage since it changes the cost structures and access to financial services. Mobile technology has played a big role in the transformation of Tanzania's financial landscape in the recent past, by providing an avenue for a large group of financially excluded populations to be formally included in the financial system.

The main objective of this study is to explore the role played by Financial technologies (FinTech) in increasing financial inclusion and how do these structural changes have brought impacts to monetary policy. This paper will contribute to the existing literature by applying of Stochastic General Equilibrium model (DSGE), to analyze how does the FinTech and financial inclusion has influenced monetary policy conduct specifically by focusing on the money demand function which is a very vital component of monetary policy under monetary aggregates framework which Tanzania uses.

To be able to assess how FinTech has helped to shape the stance of Monetary policy, we have utilized household heterogeneity by adopting a prototype of the two-agent New Keynesian (TANK) model introduced by Gali and Monacelli (2008) and Bilbiie (2008). This study extends the original model of the households heterogeneity in the inter-temporal consumption-savings behavior, through limited asset market participation (LAMP), by allowing poor households to save in bonds subject to portfolio adjustment costs. While the rich households, save in bonds without portfolio adjustment costs and are the owners of economy's firms and thus they receive the dividend.

Further, both rich and poor households are subject to transaction costs[1] which reflects and proxies the level of financial development and access to financial services, thus modified money demand functions for the rich and poor households.

A significant number of TANK models literature assumes unconstrained households who have access to financial markets to smooth their consumption and hand-to-mouth (HtM) households who don't satisfy the Permanent Income Hypothesis, see[2] This is because data on asset holding in the USA shows 0.4 to 0.5 of the US population merely consumed their current income Campbell and Mankiw (1989). Also, studies using micro-data indicate that a significant fraction of the US population fails to behave as the permanent income hypothesis suggests. Van Oudheusden et al. (2015), study survey shows that globally among the adult population in 2014, 38 percent did not own a bank account

[1] In this set up transaction costs reflects costs associated with withdrawal fees, transfer fees, time costs involved and any other costs which household is subjected to in executing transactions. These costs tend to be significantly higher among the poor.

[2] Gali et al. (2004), Motta and Tirelli (2012) and Colciago (2011)

This study adopted a middle approach where hand-to-mouth households are facing costs in adjusting their assets portfolio. This suits better the Tanzanian case as the majority of poor use informal services for saving to smooth their consumption, which is relatively more expensive and can be thought of as an extra cost to access formal financial markets. In this approach, it will be possible to have an Euler equation for poor agents and money demand function which we inter to modify to capture the effect of FinTech through transaction cost.

Jack and Suri (2014), conducted a study of the effect of decreased transaction costs on risk-sharing by using estimates from changes in consumption brought by mobile money. The study used Kenya's household panel data survey from 2008 to 2010. The results show negative shock reduces per capita consumption of nonusers by 7-10 percent as compared to users, this is due to the ability of users to smoothen their consumption due to increase in risk sharing facilitated by remittances via mobile money platforms, this can be one of the evidence that poor households have some degree of consumption smoothing.

In the recent decade, the world has witnessed massive digitization almost in all spheres of life, including the financial sector. These developments have potentially changed how the traditional financial institution was set to offer services to the public. As of recent major central banks have signed a memorandum of understanding to lay a foundation of possibilities on a future Digital currencies to cope with technological progressMancini-Griffoli et al. (2018).

In developing, nations FinTech has lead to financial inclusion where many people who were excluded from using financial products are now formally included in the system through new products such as Mobile, (M-Pesa) in Tanzania. Insights (2017) shows that adult access to formal financial services increased to 65% in 2017 from 58% in 2013, out of this inclusion 55% is through mobile money accounts. Thus this paper is motivated to investigate how these disruptions[3] have shaped the stance of

[3] In terms of Velocity and money demand tends to shift permanently due to technological innovation in financial sector Darrat (1986), Guidotti and Rodriguez (1992)

the Monetary transmission mechanism in Tanzania by using the DSGE model via heterogeneous transaction costs in the money demand function.

3.2 Literature Review

Number of studies have indicated that financial innovation tends to alter money demand and thus the velocity of money, which is essential for conducting monetary policy using monetary aggregates. Arrau et al. (1995) found that financial innovation plays an important role in determining money demand and its fluctuations and that the importance of this role increases with the rate of inflation. Ireland (1995) extends the work by Lucas and Gillman (1993) using Cash-in -advance (CIA) model, by assuming that an increase in financial capital allows the shoppers to buy more goods on credit in markets where money was importantly required. The model indicates that a temporary increase in the nominal interest rate generates a persistent increase in money velocity .

Mehrotra and Yetman (2014), modeled the access of financial services in the emerging market economy using TANK model with unconstrained and rule of thumb HtM households, to analyze how welfare-maximizing monetary policy is being affected by the level of financial inclusion. The empirical results on both developed and developing countries that operate with a reasonable degree of autonomy in conducting their monetary policy. There is a shred of strong evidence from the model's predictions, that when monetary policy is conducted optimally the ratio of output volatility to inflation volatility is increasing in the share of financially included consumers in the economy

The use of modern technology has proven to increase efficiency in the way financial institutions provide their services. This could be witnessed back in the 1970s, with the invention of the ATM, and recent the use of internet banking, which has substantially decreased transaction cost[4]. Lieberman (1977) claims that increased use of credit, better synchronization of receipts and expenditures, reduced mail float, more intensive use of money substitutes, and more efficient payments mechanisms will tend to decrease the transaction demand for money over time. It was found that money demand in the US has changed due to technological change, this was captured by the introduction of proxy for the unobserved variable 'technology', in estimating the demand for narrow money.

Areosa and Areosa (2016) used TANK model with skilled consumers who are unconstrained and can smoothen their consumption and HtM unskilled consumer who have no access to the financial system. The results are not so different from others in this literature. Monetary policy is welfare-based which includes inequality stabilization. Thus, welfare decreases as the proportion of unskilled agents increases, and when the number of unconstrained skilled consumer decreases monetary policy becomes less effective. The results suggest as financial inclusion increases monetary policy becomes more effective.

Adam and Walker (2015) developed a Dynamic Stochastic General Equilibrium (TANK) Model, with rural hand-to-mouth and urban Ricardian optimizing households for East African economies. Their paper aimed at assessment of the effects of adoption mobile to monetary policy in the region. In their approach, they modeled mobile money as remittance transfer from urban to rural households that serve as insurance against unanticipated income fluctuations to smoother rural households' consumption. Simulations results indicate that the proliferation use of mobile money potentially, helps to reduce the incompleteness of markets, thus more active monetary policy actions also their findings suggest the monetary authorities may be able usefully to shift their focus from headline inflation to core inflation.

A general number of pieces of literature comes to the same conclusion as

[4]Innovations require long-lived capital investments with very substantial sunk costs but low operating cost and, thus economizing on use of notes and coins and conceivably impacts on the demand for currency is likely to be permanent Ochs and Rush (1983)

shown by Mehrotra and Nadhanael (2016) in their study of financial inclusion impacts on economic growth, poverty reduction, and inequality as well as effective macroeconomic policies. Results established that FinTech plays a central role in enhancing financial inclusion and reduction in poverty. Also, inequality is associated with financial inclusion in the sense that the central bank's ability to stabilize economic activity is improved with the attainment of higher financial inclusion.

The rest of this paper is organized in the following sections. Section 2 presents the TANK model theoretical framework, to underpin the role played by transaction and portfolio adjustment costs to influence the effectiveness of monetary policy transmission mechanism. Section 3, presents the Model dynamics by assessing the impulse response functions under different scenarios of "Before" the introduction of electronic money and "After" introduction of electronic money and shows how has the policy being effective in delivering its intended objectives. Section 4 provides policy implications and recommendations while section 5 details the conclusion.

3.3 The Model Setup

This paper adopts and extends the DSGE framework proposed by Bilbiie (2008). Whereby the economy is assumed to consist a continuum of infinitely lived households, a continuum of firms producing differentiated intermediate goods, final good producing firms in monopolistic competition and staggered price setting, and a central bank determining monetary policy.

The infinitely lived households are of two types who are different in respect to two dimensions:

i) The type of income they have in their budget constraints.

ii) The type of market frictions the household is subjected to.

Households have similar preferences and each of them optimally chooses consumption, real money balance, assets holding, and hours of labor supply.

The model features staggering prices Calvo (1983), and a (normalized) CES production function with fixed costs Bilbiie (2008) and Cantore and Freund (2020). The model simulations are based on monetary shocks under the different transaction and portfolio adjustment costs parameterization.

3.3.1 Households

There is a continuum of households, indexed by j, such that $j \in [0, 1]$. It is assumed all households are Ricardian and smooth consumption, by participating in markets for state-contingent securities. A fraction[5] α of households have limited participation in financial markets since they need to incur extra cost, they are denoted as poor, (p). The remained $1 - \alpha$ they don't face friction in accessing the financial markets and they are termed a rich (r) , thus $i = p$ if $j \in [0, 1 - \lambda]$ and $i = r$ if $j \in [1 - \alpha, 1]$.

Households' preferences are characterized by CRRA, money-in-utility (MIU) function, a model introduced by Sidrauski (1967). It assumes that real money holdings increase the welfare of economic agents and therefore that money can be incorporated directly into the household's utility functions.

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{(C_{i,t+k})^{1-\sigma}}{1-\sigma} + \frac{(M_{i,t+k}/P_{t+k})^{1-\eta}}{1-\eta} - \chi_n \frac{(N_{i,t+k})^{1+\psi}}{1+\psi} \right\} \quad i \in (p, r)$$

This utility function is then maximized subject to a sequence of budget constraints that are different between poor and rich households, in solving the inter-temporal allocation problem.

[5] The fractions of rich and poor households are exogenously determined in the model.

3.3.1.1 Rich households Optimal allocation

It is assumed rich households don't incur transaction cost in accessing financial market since the financial infrastructures are well developed and the market are centered in the urban sector where they live. Also, they are owners of intermediate firms and thus receive profit in form of a dividend.

The utility maximization problem of the rich household becomes,

$$\begin{aligned}
&Max \sum_{k=0}^{\infty} \beta^k U(C_{r,t+k}, M_{r,t+k}, N_{r,t+k}) \\
&\textit{subject to} \\
&B_{r,t} + \Omega_{r,t+1} V_t + M_{r,t} + P_t C_{r,t} \leq \Omega_{r,t}(V_{r,t} + P_t D_{r,t}) \\
&+ N_{r,t} W_t + R_{t-1} B_{r,t-1} + M^r_{r,t-1} + D_{r,t}
\end{aligned} \tag{3.1}$$

Where $\Omega_{r,t}$ are shareholdings, D_t is shares' real dividend payoffs, V_t is shares' average market value at time t, $B_{r,t}$ and $M_{r,t}$ are the nominal value of the bond and money holding respectively at the end of period t.

Solving for rich household problem in (3.1) leads to the following optimal first-order conditions at each date in each state.

$$\begin{aligned}
&\textit{Euler equation} \\
&\frac{1}{R_t} = \beta E_t \left[\frac{C^{\sigma}_{r,t}}{C^{\sigma}_{r,t+1}} \frac{P_t}{P_{t+1}} \right] \\
&E_t(C^{\sigma}_{r,t+1}) = \beta C^{\sigma}_{r,t}
\end{aligned} \tag{3.2}$$

$$\begin{aligned}
&\textit{Labor supply} \\
&\frac{W_t}{P_t} = \chi_n (N_{r,t})^{\psi} C^{\sigma}_{r,t}
\end{aligned} \tag{3.3}$$

$$\begin{aligned}
&\textit{Real Money balance} \\
&\frac{C^{\sigma}_{r,t}}{(m_{r,t})^{\eta}} = 1 - \frac{1}{R_t}
\end{aligned} \tag{3.4}$$

3.3.1.2 Poor households Optimal allocation

A significant number of household on $[0, \alpha]$ range, are poor and the majority lives in the rural areas. Where the level of financial infrastructure is considered inadequate, thus exist friction to access the financial markets Schmitt-Grohé and Uribe (2003). The friction can be in form of a simple quadratic form, denoted by AC_t[6]

Rural households budget constraint is given by

$$B_{p,t} + P_t AC_t + M_{p,t} + P_t C_{p,t} = N_{p,t} W_t + R_{t-1} B_{p,t-1} + M_{p,t-1} \tag{3.5}$$
$$where \quad AC_t = \frac{\Psi}{2}\left[B^r_{p,t} - B_p\right]^2$$

Of which B_p is the steady-state level of bond holding, and Ψ is the portfolio adjustment cost. The adjustment costs affect the Euler equation through inter-temporal consumption choice.[7] Solving the households optimization problem of choosing bond, money holding and consumption leads to the following first order conditions;

Euler equation

$$\frac{1}{R_t} = \beta E_t \left[\frac{C_{p,t+1}}{C_{p,t}} \frac{P_t}{P_{t+1}}\right] (1 + \Psi(b_{p,t} - b_p))^{-1}$$
$$E_t(C_{p,t+1}) = \beta C_{p,t}[1 + \Psi(b_{p,t} - b_p] \tag{3.6}$$

Labor supply

$$\frac{W_t}{P_t} = \chi_n (N_{p,t})^{\psi} C_{p,t} \tag{3.7}$$

Real Money balance

$$\frac{C_{p,t}}{(m_{p,t})^{\eta}} = 1 - \frac{1}{R_t}[1 + \Psi(b_{p,t} - b_p] \tag{3.8}$$

[6] AC Costs are paid in terms of output and at the steady state are non-zero thus in the long run generating a non-zero demand for bonds.

[7] An increase in the cost of bonds trading reduces wealth's accumulation sensitivity from changes in the interest rate, since it becomes more costly to smooth consumption. Increase in this parameter indicates it's more costly in accessing the financial markets.

3.3.2 Firm's Problem

There are two types of firms, intermediate and final goods-producing firms. Intermediate goods-producing firms employ labor as their only sole input to produce differentiated goods which they sell in the monopolistically competitive market with sticky prices.

The representative final output producing firm uses input from intermediate firms and bundles them as final goods, that are sold in competitive markets with flexible prices. This implies that the price of the final goods equals their marginal cost and firms earn zero profit. Final goods are bundled using CES technology, with ϵ[8] denoting constant elasticity of substitution of goods Y_i.

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \tag{3.9}$$

Where $Y_t(i)$ denotes differentiated good i at time t. The final good producing firm maximizes profit

$$P_t Y_t - \int_0^1 P_t(i) Y_t(i)$$

Subject to constant return to scale

$$Y_t \leq \left(\int_0^1 Y_t(i)^{\frac{1-\epsilon}{\epsilon}} di \right)^{\frac{1}{1-\epsilon}}$$

Thus the firms problem can be written as

$$\underset{Y_t(i)}{Max}\ \Pi_t \quad = P_t \left[\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}} - \int_0^1 P_t(i) Y_t(i) di$$

[8] The higher is ϵ the more substitutable these goods becomes (closer to perfect substitute goods).

The First order conditions;

$$\frac{\partial \Pi_t}{\partial Y_t(i)}: \quad \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t = Y_t(i) \tag{3.10}$$

Substituting (??) into CES aggrigator in (3.9)

$$P_t = \left(\int_0^1 P_t(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}} \tag{3.11}$$

Where P_t is the overall price index for the final good, $P_t(i)$ price of intermediate good i and $Y_t(i)$ downward sloping demand[9] curve for intermediate goods.

The representative Intermediate firm's problem maximizes profits by minimizing cost in the choice of factors of production and also setting an optimal price when they are given the chance to re-optimize. The process of adjusting the prices is random and time-dependent. Walsh (2017).

3.3.2.1 Cost Minimization

The monopolistically competitive producers maximize profit subject to the demand for their output and production technology which is linear in labor and subject to a fixed[10] cost F.

$$Y_t(i) = A_t N_t(i) - F, \quad \text{if } N_t(i) > F; \quad \text{otherwise } Y_t(i) = 0 \tag{3.12}$$

Where $N_t(i)$, is the labor input and A_t, is a stochastic aggregate productivity [11] with constant returns to scale. The firm's cost $W_t N_t(i)$, minimization problem given wage and the available state of technology $A_t = (Y_t(i) - F)/N_t(i)$, leads us to the firm's marginal cost.

[9] A 1 percent increase in the relative price of good i leads to its reduction by ε percent

[10] The share of the fixed cost F in steady-state output governs the degree of increasing returns to scale.

[11] $E(A_t) = 1$

$$
\begin{aligned}
\mathcal{L} = & \underset{N_t(i)}{Min} \left(\frac{W_t}{P_t}\right) N_t(i) + \varphi_t (Y_t - A_t N_t(i) + F) \\
\frac{\partial \mathcal{L}}{\partial N_t(i)} : & \quad \frac{W_t}{P_t} = \varphi_t A_t \\
\varphi_t = & \frac{W_t / P_t}{A_t}
\end{aligned}
\tag{3.13}
$$

where $Mc_t = \varphi_t$, is the real marginal which which is the same for all firms.

3.3.2.2 Optimal price setting

Intermediate firms produce differentiated goods in a monopolistically competitive market structure which gives market power in setting their prices. Following Calvo (1983) to accommodate inflation persistence observed in real data, it is assumed that in both sectors, each period some firms are not able to adjust their prices. Firms that adjust their price are randomly selected which is $1 - \omega$ the fraction of all firms while the remaining ω indexes their price to a previous-period $t - 1$ inflation Senaj et al. (2010). The firms' probability of re-optimizing in any given period being independent of the time elapsed since it last reset its price. Therefore the average price in the period t satisfies, the following law of motion;

$$
P_t^{1-\epsilon} = (1 - \omega)(P_t^*)^{1-\epsilon} + \omega P_{t-1}^{1-\epsilon} \tag{3.14}
$$

The firm which re-optimizes in period t will choose the price P_t* that maximizes current market value of the profits generated while that price remains effective.

$$\begin{aligned}
&\underset{P_t^*}{\text{Max}}\ E_t \sum_{k=0}^{\infty} \omega^k Q_{t,t+k} \Big[P_t^*(i) Y_{t+k}(i) - TC_{t+k}(i)\big(Y_{t+k}(i)\big) \Big] \\
&s.t \\
&Y_{t+k}(i) = \left(\frac{P_t^*(i)}{P_{t+k}} \right)^{-\epsilon} C_{t+k}, \\
&Y_{t+k}(i) = A_t N_t(i)
\end{aligned} \tag{3.15}$$

where $Y_{t+k}(i)$ is the firm's output in $t+k$ that adjusts price in t, $TC_{t+k}(i)\big(Y_{t+k}\big)$ is the firm's total cost in period $t+k$ as the functions of its output and stock holder's stochastic discounting factor is given by the $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma}$.

Solving problem in (3.15) leads to the firms optimal relative price

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{1-\epsilon} \frac{E_t \sum_{k=0}^{\infty} \omega^k \beta^k Mc_{t+k} (C_{t+k})^{1-\sigma} \left(\frac{P_{t+k}}{P_t} \right)^{\epsilon}}{E_t \sum_{k=0}^{\infty} \omega^k \beta^k (C_{t+k})^{1-\sigma} \left(\frac{P_{t+k}}{P_t} \right)^{\epsilon-1}} \tag{3.16}$$

Under flexible prices settings when the value of $\omega_t = 0$, (3.16) becomes

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{\epsilon-1} \frac{\omega^0 \beta^0 Mc_t (C_t)^{1-\sigma} (1)^{\epsilon}}{\omega^0 \beta^0 (C_t)^{1-\sigma} (1)^{\epsilon-1}} = \frac{\epsilon}{\epsilon-1} MC_t \tag{3.17}$$

In a zero inflation steady-state $\Pi_t = \frac{P_t^*}{P_{t-1}} = \frac{P^*}{P} = 1$ and letting $\mathcal{Z}_t$ being optimal relative price $\frac{P_t^*}{P_t}$ and $\mathcal{M} = \frac{\epsilon}{1-\epsilon}$. In the flexible price equilibrium $\mathcal{Z}_t$ can be written as $\mathcal{Z}_t = \mathcal{M} Mc_t = 1$

By taking first order Taylor expansion of (3.14) *in a zero inflation steady state*

$$\hat{z}_t = \left(\frac{\omega}{1-\omega}\right)\Pi_t$$

Approximation of (3.16) *using First order Taylor expansion results to*

$$\hat{z}_t = (1-\omega\beta)\hat{M}c_t + \omega\beta(\hat{z}_{t+1} + \Pi_{t+k})$$

Combining these two conditions results to NK-Phillips Curve

$$\Pi_t = \beta\Pi_{t+k} + \tilde{\kappa}\hat{M}c_t \tag{3.18}$$

3.3.3 Money velocity and transaction cost

The most important part to model the role of financial innovation and technology in this model is unveiled in the money demand function. By keeping the model simple we adopted the money demand function proposed by Arrau et al. (1995), which is a variant of the Cagan model.[12] The money demand function proposed included transaction technology that could be interpreted as the number of resources spent in shopping activities.

$$h\left(\frac{m_t}{c_t^{\phi}}, \theta_t\right) = -\frac{i_t}{1+i_t}$$

$$log(m_t) = log(\theta_t) + log(c_t) - \alpha\frac{i_t}{1+i_t}$$

Where θ_t represents a state of transaction technology, hence a reduction in this parameter reduces the cost of transactions[13] which is associated with (positive) financial innovation.

Mobile money has resulted into decrease in transaction cost in terms of deposit

[12]The model describes individuals' demand for money and the evolution of inflation expectations over time, which implies that the velocity of money is increasing in the nominal interest rate.

[13] Mbiti and Weil (2015), Mobile money has decreased prices of competing money transfer services such as Western Union and has facilitated an increase of banking products as customers have virtual bank accounts on the mobile money service provider.

and withdrawal fees as well as cost in participating in financial markets. This change in cost has been in favor of poor households since before the use of mobile it was more expensive for the poor to access financial services as compared to the rich. This makes the specification of a transaction cost function for rich $Tc_{r,t} = V_t^{-\gamma_r}$ and $Tc_{p,t} = V_t^{-\gamma_p}$ for poor households.

Given the specification of transaction functions for both rich and poor households, their real money balances in (3.4) and(3.8) becomes as follows;

$$\Big(\frac{M_{p,t}}{P_t}\Big)^{\eta} = C^{\sigma}_{p,t}\Big(\frac{1+i_t}{i_t}\Big)[1+\Psi(b_{p,t}-b_p] + Tc_{p,t} \tag{3.19}$$

$$\Big(\frac{M_{r,t}}{P_t}\Big)^{\eta} = C^{\sigma}_{r,t}\Big(\frac{1+i_t}{i_t}\Big) + Tc_{r,t} \tag{3.20}$$

Transaction cost Tc_t, is a decreasing function of velocity V_t for all values of $\gamma > 0$, which implies higher velocity and advanced financial architecture. Therefore demand for real balances is negatively related to the velocity of money in circulation and related positively to the level of income.

3.3.4 Market Clearing

Market clearing in the goods markets requires that,

$$Y_t(i) = C_t(i) \tag{3.21}$$

By using CES aggregation, the total output can be defined as,

$$Y_t \equiv \left(\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \tag{3.22}$$

$$Y_t = C_t \quad \text{holds for all } t. \tag{3.23}$$

Using the production technology and demand function in (3.10), it implies that

$$A_t N_t(i) - F = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t$$

By integration over i on both sides,

$$\int_0^1 A_t N_t(i) di, -F = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t di \tag{3.24}$$

$$A_t \int_0^1 N_t(i) di - F = Y_t \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di$$

By defining ne variable Δ_t

$$\vartheta_t = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di \tag{3.25}$$

$$A_t N_t - F = Y_t \Delta_t \tag{3.26}$$

Price dispersion is measured by Δ_t. In the situation with no pricing friction, every firm charges the same price thus $\Delta_t = 1$. But when $\Delta_t \geq 1$, results in output loss given A_t, since the production would be less than the other Woodford (2011).

Clearing conditions in money markets :

$$M_t \equiv \int_0^1 M_t^j dj = \alpha M_{p,t} + (1-\alpha) M_{r,t} \tag{3.27}$$

$$Tc_t = \alpha Tc_{p,t} + (1-\alpha) Tc_{r,t} \tag{3.28}$$

$$B_t = \alpha B_{r,t} + (1-\alpha) B_{p,t} \tag{3.29}$$

$$B_t = 0 \tag{3.30}$$

Labor market clears when labor demand by all firms equal aggregate households labor supply and goods market clears when total consumption equal to individual composite demands consumption indexed over $\in [0, 1]$

$$N_t = \alpha N_{p,t} + (1-\alpha)N_{r,t} = \int_0^1 N_t^j dj \tag{3.31}$$

$$C_t \equiv \alpha C_{p,t} + (1-\alpha)C_{r,t} = \int_0^1 C_t^j dj \tag{3.32}$$

State-contingent assets are in zero net supply (markets are complete and agents trading in them are identical). Bilbiie (2008), whereas equity market-clearing implies that shareholdings of each asset holder are $\Omega_{r,t+1} = \Omega_{r,t} = \Omega = \frac{1}{1-\lambda}$. Representative intermediate firms' real profit is given by

$$D_t(i) = \frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t}{P_t} N_t(i)$$

Given firm's demand curve in (3.10), and real marginal cost in (3.13) the economy's total profit which goes to rich households who own the firm as dividend becomes,

$$D_t = Y_t - \frac{MC_t}{P_t} Y_t \Delta_t \tag{3.33}$$

3.3.5 Log-linear equilibrium and steady state

In analyzing the dynamics of the model we use its log-linear approximation around its non-stochastic steady state that is unique. The equilibrium conditions around this steady-state are indicated by small case letters showing the log-deviation of a variable from its steady-state, $\hat{x}_t = log(X_t/X) \simeq (X_t - X)/X$, $\hat{\pi}_t = log(P_t/P_{t-1})$, $\hat{i}_t = i_t - i$ and share of real profit to income $\tilde{d}_t = (D_t - D)/Y$,

In a stationary equilibrium with zero inflation, the gross interest rate is equal to the inverse of the inter-temporal discount factor, $R = \beta^{-1} \equiv 1 + r$. Share of total profit to income in the steady state of (3.33), is $D_Y = (\mu - F_Y)/(1+\mu)$ by assuming $\mu = (\varepsilon - 1)^{-1}$ and share of labor income to output is $WN/PY = (1 + F_Y)/(1 + \mu)$ $F_Y \equiv F/Y$ where is share of fixed cost to total output.

Table 3.1: TANK Model Summary.

Description	Equation
Euler Equation R	$\hat{c}_{r,t} = \hat{c}_{r,t+1} - \hat{r}_t$
Euler Equation P	$\hat{c}_{p,t} = \hat{c}_{p,t+1} - \hat{r}_t + \Psi\tilde{b}_{p,t}$
Budget Constraint R	$\tilde{b}_{r,t} = \hat{n}_{r,t} + \hat{w}_t + R\tilde{b}_{r,t-1} - \hat{c}_{r,t} + \frac{\tilde{d}}{1-\alpha}$
Budget Constraint P	$\tilde{b}_{p,t} = \hat{n}_{p,t} + \hat{w}_t + R\tilde{b}_{p,t-1} - \hat{c}_{p,t}$
Dividend	$\tilde{d}_t = -\hat{m}c_t + \frac{\mu}{1+\mu}\hat{y}_t$
Labor Supply R	$\hat{c}_{r,t} = \hat{w}_t - \varphi\hat{n}_{r,t}$
Labor Supply P	$\hat{c}_{p,t} = \hat{w}_t - \varphi\hat{n}_{p,t}$
Real Marginal Cost	$\hat{m}c_t = \hat{w}_t - \hat{a}_t$
Phillips Curve	$\pi_t = \beta\pi_{t+1} + \tilde{\kappa}\hat{m}c_t$
Production Function	$\hat{y}_t = (1+\mu)a_t + (1+\mu)\hat{n}_t$
Aggregate Labor Supply	$\hat{n}_t = \alpha\hat{n}_{p,t} + (1-\alpha)\hat{n}_{r,t}$
Aggregate Consumption	$\hat{c}_t = \alpha\hat{c}_{p,t} + (1-\alpha)\hat{c}_{r,t}$
Transaction Cost R	$\hat{T}c_{r,t} = -\gamma_r\hat{v}_t$
Transaction Cost P	$\hat{T}c_{p,t} = -\gamma_p\hat{v}_t$
Total Transaction Cost	$\hat{T}c_t = \alpha\hat{T}c_{p,t} + (1-\alpha)\hat{T}c_{r,t}$
Real Money Balance R	$\hat{m}_{r,t} = \frac{1}{\eta}\left(\sigma\hat{c}_{r,t} - \zeta\hat{i}_t + \hat{T}c_{r,t}\right)$
Real Money Balance P	$\hat{m}_{p,t} = \frac{1}{\eta}\left(\sigma\hat{c}_{p,t} - \zeta\hat{i}_t + \hat{T}c_{p,t} + \Psi\tilde{b}_{p,t}\right)$
Total Money Balance	$\hat{m}_t = \alpha\hat{m}_{p,t} + (1-\alpha)\hat{m}_{r,t}$
Bond Market Clearing	$\hat{b}_t = \alpha\hat{b}_{p,t} + (1-\alpha)\hat{b}_{r,t}$
Real Interest Rate	$\hat{r}_t = \hat{i}_t - \hat{\pi}_{t+1}$
Inflation	$\hat{\pi}_t = \hat{p}_t - \hat{p}_{t-1}$
Money Supply	$\hat{m}s_t = \hat{m}_t + \hat{p}_t$
Monetary Policy	$\hat{\lambda}_{m,t} = \hat{m}_t - \hat{m}_{t-1} + \hat{\pi}_t$
Money Velocity	$\hat{v}_t = \hat{c}_t - \hat{m}s_t$
TFP Process	$\hat{a}_t = \rho_a\hat{a}_{t-1} + \hat{\xi}_{a,t}$
Money growth Process	$\hat{\lambda}_{m,t} = \rho_m\hat{\lambda}_{m,t-1} + \hat{\xi}_{m,t}$

3.3.6 Monetary Authority

The central banks of many SSA countries conduct monetary policy through a combination of direct instruments (e.g. reserve requirements) as well as foreign exchange interventions and open market operations with the private sector that affect the monetary base. Therefore, like Adam et al. (2009) andBuffie et al. (2004), The analysis of the impact of FinTech on monetary policy in Tanzania is done by using the framework of monetary aggregates whereby the monetary authority sets a target of money growth and use base money as the operational target, thus the central bank is set to stabilize some measure of inflation around a target.

In this regard following Danthine and Kurmann (2004) Monetary authorities exogenously set the (net) growth rate of money $\lambda_{m,t}$, such that the supply of real balances evolves according to the following simple money creation process

$$M_t = (1 + \lambda_{m,t})M_{t-1} \tag{3.34}$$

$$\hat{\lambda}_{m,t} = \hat{m}_t - \hat{m}_{t-1} + \hat{\pi}_t \tag{3.35}$$

The sign on growth rate parameter can reflect the stance of monetary policy, such that $\lambda_{m,t} > 0$ indicates expansionary policy while $\lambda_{m,t} < 0$ means contractionary policy. The dynamics of the money growth rate follows an AR(1) process such that;

$$\lambda_{m,t} = \rho_m \lambda_{m,t-1} + \xi_{m,t} \tag{3.36}$$

Where $\xi_{m,t}$ Is the white noise exogenous monetary policy shock, which can be interpreted as the unsystematic component of monetary policy.

3.4 Model Dynamics

3.4.1 Calibration

The baseline calibration of this paper follows previous studies, that are used in a standard DSGE literature, Table 3.1. Approximately 72 %[14] of Tanzanians live in a rural area, this ratio is used to represent the poor households and set parameter α to be 0.72. Transaction cost parameter γ for both rich and poor in the regimes before and after the introduction of mobile money is arbitrarily calibrated based on higher and low values that fit better the model dynamics.

The Calvo parameter is set at 0.66 Rotemberg and Woodford (1997), this means that prices remain fixed for a mean duration of 3 quarters which is consistent with the micro evidence for developing economies Prasad and Zhang (2015) and Adam and Walker (2015). Since most economies in SSA including Tanzania, they are dominated by agricultural economies which their prices are relatively likely to change more frequently compared to economies that are dominated by the manufacturing sector.

The standard deviation of monetary policy shock is set at 25 basis points, which implies that, annualized 1 percentage point. On the other hand, the standard deviation for total factor productivity is set to 0.5 as the benchmark value. The persistence of monetary policy shock is set at 0.5 which is a common value used in literature as empirical studies show the autocorrelation of money growth is approximately around that value. The persistent parameter of productivity shock is fairly considered to be 0.75 this is up from 0.04 from the one set by Adam and Walker (2015).

[14] Annual percentage average of population living in rural area, from 2000 to 2019 UN-DESA (2018)

Gandelman and Hernández-Murillo (2015) estimated CRRA coefficient for Tanzania which results shows it ranges between 0.5 to 2.1 with its median value slightly above 1.5, in estimation a value of 1.7 is chosen. Goldberg (2016) estimated value of the inverse of Frisch elasticity in Malawi and the results indicate it ranges between 0.15 to 0.17, an average of 0.15 is taken as the baseline value.

Table 3.1: Baseline Calibrated Parameters

Parameter	Description	Comment
$\beta = 0.98$	Subjective discount factor	Calculations from the data
$\sigma = 1.70$	Relative Risk Aversion coefficient	
$\varphi = 0.15$	Inverse of Frisch elasticity	Goldberg (2016)
$\eta = 1$	Real money balance preference	Galí (2008)
$\zeta = 4$	interest-elasticity of the demand for money	Galí (2008)
$\alpha = 0.72$	Share of Poor households	Calculations from the data
$\theta = 0.66$	Calvo price stickiness parameter	Prasad and Zhang (2015)
$R_{ss} = \beta^{-1}$	Steady state gross nominal interest rate	
$\epsilon = 10.0$	Elasticity of substitution among varieties	Woodford (2011)
$\Psi = 0.25$	Portfolio adjustment cost	Cantore and Freund (2020)
$\rho_a = 0.79$	Persistence of productivity shock	Anand and Prasad (2010)
$\rho_m = 0.5$	Persistence of monetary policy shock	Galí (2008)
$\sigma_a = 0.5$	Standard deviation of technology shock	Galí (2015)
$\sigma_m = 0.25$	Standard deviation of monetary shock	Galí (2008)
$\gamma_p = 0.95$	Poor households transaction cost (High)	Benchmark
$\gamma_r = 0.35$	Rich households transaction cost (High)	Benchmark
$\gamma_p = 0.50$	Poor households transaction cost (Low)	Benchmark
$\gamma_r = 0.05$	Rich households transaction cost (Low)	Benchmark

3.4.2 Impulse Response Function

This section, discusses how monetary policy will perform when the economy is subjected to different shocks under two main scenarios. The first is when transaction cost decreases, thanks to the widespread use of electronic money especially for the poor households whose majority had no access to formal financial services. The second scenario is a changed portfolio adjustment cost which has widened an opportunity for people to be actively involved in the financial system since technology has rapidly improved the payment infrastructures.

Transaction cost

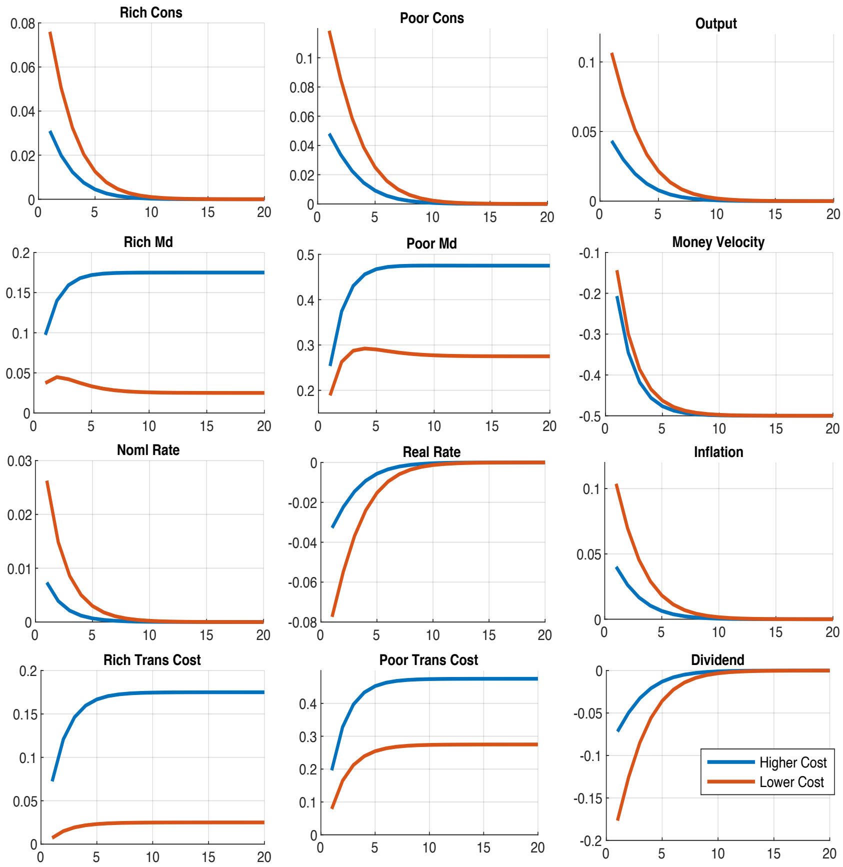

Figure 3.1: IRF's to Monetary Policy Shock, (Money Growth Rule)

As noted by Christiano et al. (1999), Andrés et al. (2002), and the IS-LM framework, under separable preferences, a positive monetary shock leads to a fall in interest rates if the risk aversion parameter is high enough Galí (2002). Implying a low degree of intertemporal substitution generates a large impact response of current consumption relative to future consumption.

Figure 3.1 shows the case of holding adjustment costs constant but changing transaction costs from higher to lower. An unexpected increase in money supply under a price stickiness setting makes non-updating firms not adjust their prices. This leads to low relative prices, the lower prices tend to stimulate demands for those goods, which makes overall output rise by more than it would if prices were flexible. To cope up with higher demand, firms must increase wages to induce longer working hours, which increases firms' marginal cost thus exerting pressure on prices and inflation. This phenomenon generates higher inflation expectations thus increases the current inflation.

From the Fisher equation, the larger increase in inflation leads to an immediate reduction in the real interest rate and further increases output. Mobile money has led to a reduction in transaction costs and an increase in money velocity. Using the quantity theory relation which assumes constant velocity. The scenario of expansionary policy with higher money velocity makes inflation increase more proportionately thus a sharper decrease in real rates as compared when transaction costs are higher and money velocity is relatively constant. Therefore, monetary policy becomes more effective in affecting real variables in the environment of mass adoption of mobile money and financial inclusion. Adam and Walker (2015).

Figure 3.2: shows results from Technology shock, in the scenario of decrease in transaction costs but keeping adjustment cost constant. Labor productivity increases, which in turn exerts an upwards pressure on the real wages. The rising real wages lead to an increase in consumption and output, due to the income effect. Labor prefers leisure to work hence reduces the number of hours for work.

Technology shocks seem not to affect monetary policy significantly enough since, in the second scenario of lower transaction costs, output and consumption are slightly lower for at least 4 quarters before the reaction becomes the same as for the case of the higher transaction cost.

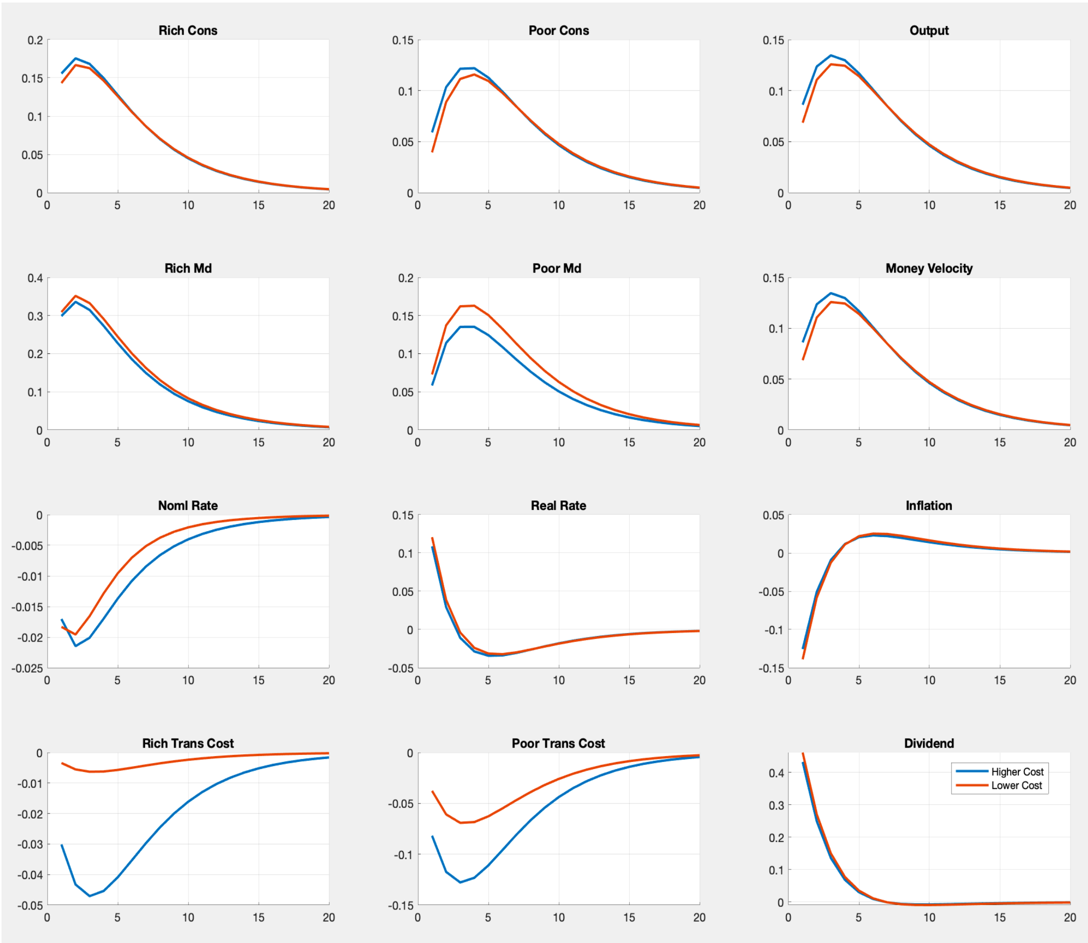

Figure 3.2: Impulse Response Function to Technology Shock

Portfolio adjustment cost sensitivity analysis

In the scenario of holding transaction costs constant at $\gamma_p = 0.95, \gamma_r = 0.350$ while allowing for decrease in adjustment cost from $\Psi = 0.25$ to $\Psi = 0.0025$. Given the fact that the introduction of mobile money has provided a platform for more poor households to participate in bond markets at a lower cost.

The simulations in figure 3.3: indicate that shock to monetary policy has a redistribution effect by increasing somewhat rich households' consumption. The decrease in transaction costs in the bond market leads to overall increase in bond holding among the poor households since they constitute the largest share of the population in the economy.

Generally the change in the bond adjustment cost has no significant change in affecting real variables when the economy experience unexpected increase in money supply. Lowering adjustment costs is not significant in explaining the benefit of mobile money and financial inclusion particularly in this model. Therefore the only cost which seems to have significant impact is transaction cost.

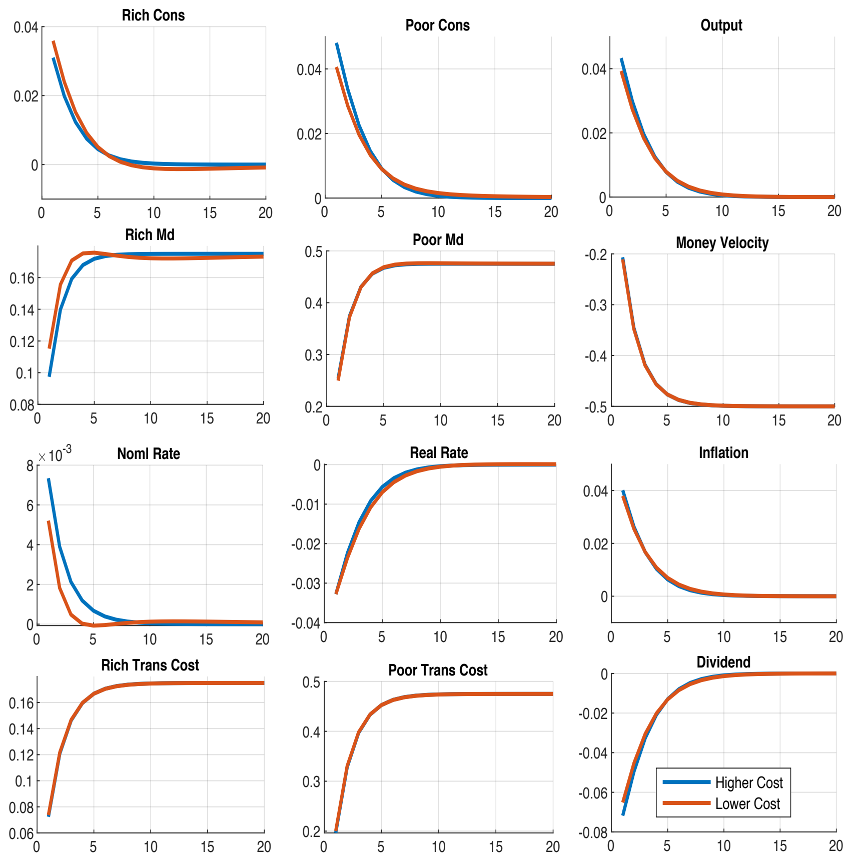

Figure 3.3: IRF of Monetary Policy Shock (adjustment cost)

Figure 3.4: Summarizes the effects of expansionary monetary policy on money growth. The overall impact of the introduction of mobile money to the economy has caused a decrease in both transaction costs and portfolio adjustment costs that ultimately led to a more responsive reaction of key macroeconomic variables from monetary policy actions.

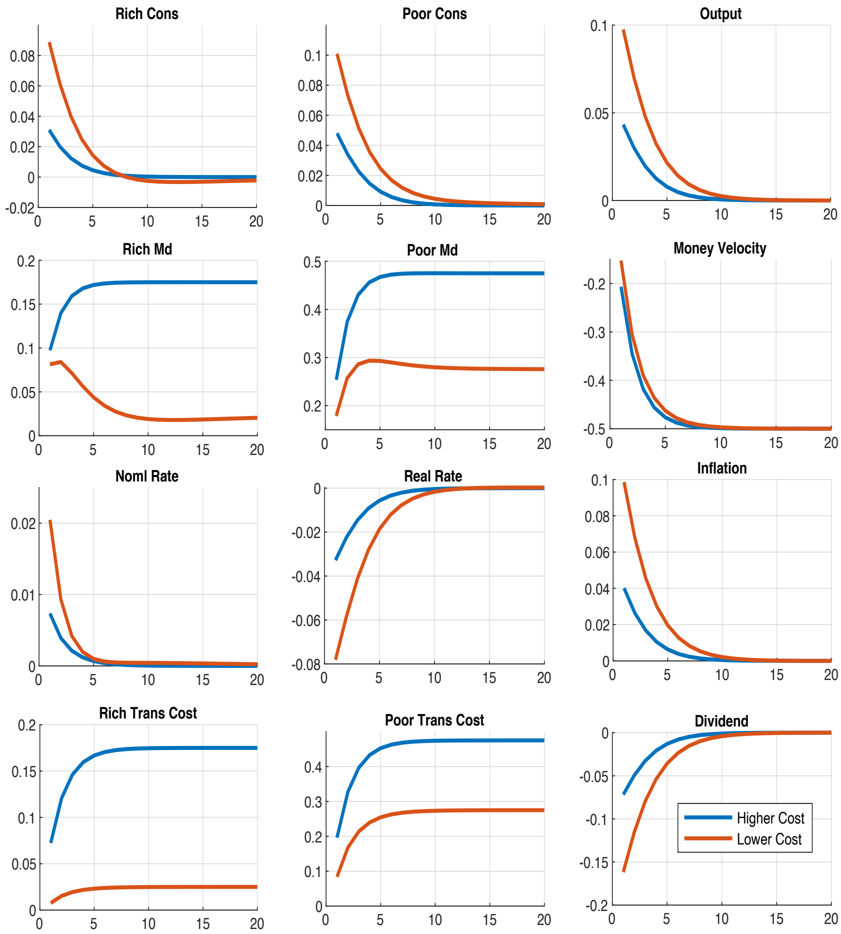

Figure 3.4: Impulse Response Function to Monetary Policy Shock

Money supply shocks result to a significant increase in money velocity, this can be due to enhancement of financial inclusion via mass adoption of different FinTech products. FinTech enables money to move more smoothly across different sectors and exchange hands between many people at a relatively higher speed. however, decrease in adjustment cost has no as significant impact as transaction cost.

Studies show that an increase in financial inclusion is associated with a more effective monetary policy transmission mechanism. According to Khan et al. (2011) financial inclusion gives an avenue to access more of the basic financial services such as credit, savings, and insurance. This provides avenue for an increase in economic activities, higher disposable income, more deposits, and employment opportunities for rural households.

The model simulations have indicated mobile money has widened the scope of the excluded populace to formal financial services which in turn gives a favorable platform for monetary policy to be more effective.

3.4.3 Regime Switching VAR Comparison

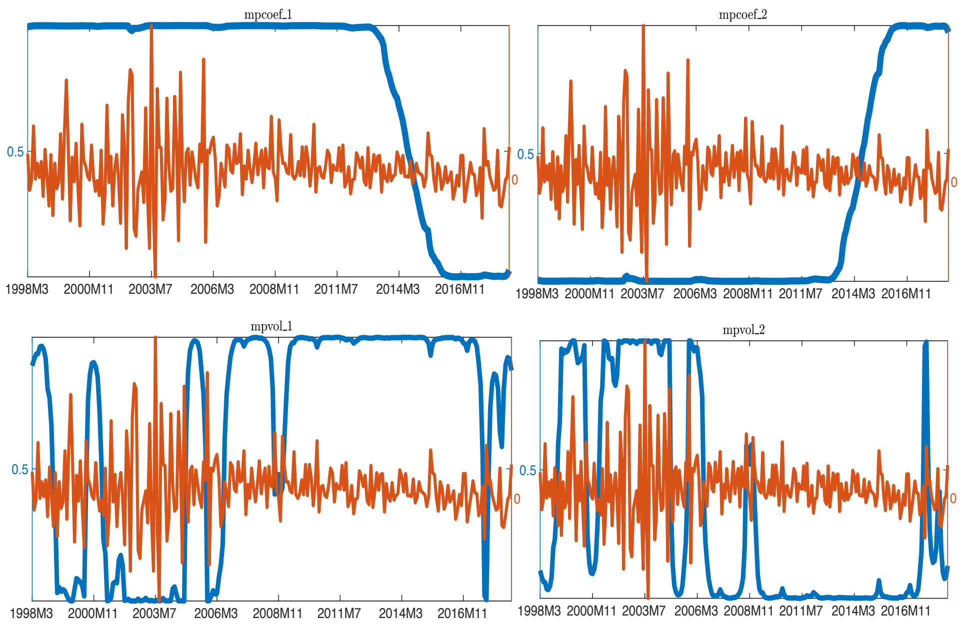

Figure 3.5: Smoothed States Probabilities and Reserves

The empirical evidence from regime-switching VAR, using Tanzania monthly data from 1998 to 2018, suggests that there is a regime shift in monetary policy conduct. The SVAR results indicate law of motion underlying the economy has changed, and these changes can be associated with several factors including the introduction of mobile, mobile, and agent banking since.

Figure 3.5: shows in 2013 monetary policy switched from Low(mpcoef1) to High(mpcoef2) state. At this time mobile money became popular and was gaining a significant number of new users after its launch in 2007. On the other hand volatility switched, from High(vol2) to Low(vol1) in 2009 and briefly 2017. The Switching is largely driven by monetary operational target (Reserves).

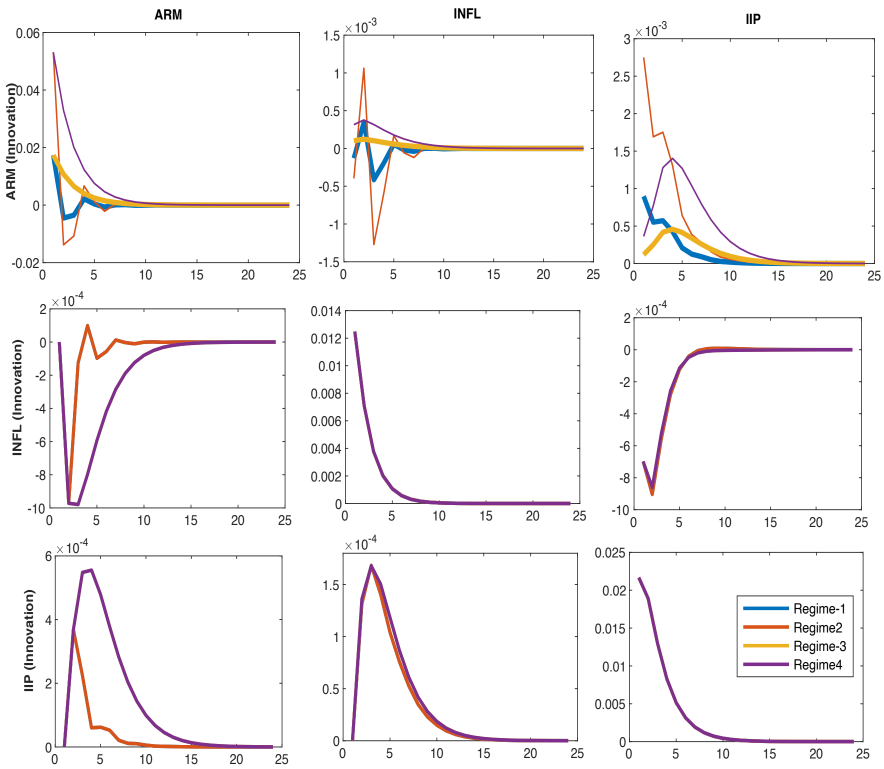

Figure 3.6: Regime Switching Impulse Response Function

Impulse response function in Figure 3.6: shows that, innovations in monetary policy have smoother and persistence increase in output and inflation in Regime3(yellow) compared to Regime1(blue) period before M-Money. This innovation has enhanced financial inclusion thus increased traction in Monetary policy effectiveness.

3.5 Policy Implication and Recommendation

There is no doubt that financial innovations coupled with financial technologies have resulted to change in the interrelationship between economic variables. This calls attention to monetary authority with the mandate of ensuring price and financial stability to pay close attention to the challenges and impacts FinTech to the evolution of money aggregates and other variables closely associated with them.

Financial Innovation has provided households with access to formal financial markets thus to services and instruments that facilitate borrowing and savings which increases the amount of cash and assets in the banking system. Subsequently, monetary policy actions become more effective since changes in the operational target such as reserve money will have direct effects on money supply, therefore improving the effective implementation of monetary targeting. However, this comes with the challenge of volatility in velocity which hence instability in the money demand function.

To ensure a more effective monetary policy given the current environment the Bank of Tanzania has to consider adopting using interest rate as an operating target while the supply of reserves via transfers or open market operations, serves as the policy instrument to implement the desired interest rate targets. As a greater share of economic activity will be influenced by central bank interest rates due to more inter-linkage. This implies that changes in policy interest rate will have a greater more direct effect on myriad household's inter-temporal consumption and investment decisions.

3.6 Conclusion

This paper has attempted to explain the regime change in Tanzania's monetary policy using a more rigorous structural model. VAR models highlighted a change in monetary policy transmission mechanism and model simulations in this chapter showed a consistent verdict that regime in monetary policy has changed and is getting more effective and its likely due to mobile money and financial inclusion.

Studies show financial inclusion has mostly been enabled by advancement in technology in providing financial services like the invention of ATMs in the 1970s, use of internet, and agent and mobile banking, significantly reduces transaction costs. For the case of Tanzania Mobile money has provided households with access to formal financial services, which previously were insulated or far reached by monetary policy actions due to the higher costs associated with these services.

In this chapter it's established that a decrease in transaction cost improves transmission mechanism of monetary policy by a stronger reaction in output consumption and inflation as compared to the scenario of the higher transaction cost. Nevertheless, decrease in transaction cost has no significant gain in terms of a more effective monetary policy in fine-tuning the economy.

As a limited study, further research is needed to better articulate the potential impact of mobile money channels on monetary policy actions. This study has looked at the aspects of transaction cost and velocity that have resulted to change in the regime but that can not be exhaustible, to better quantify the direct impact of mobile money, there should be the isolation of all possible factors which are potential to change the transmission mechanism and assess their contributions to the switch.

Appendix

Appendix 3.A Households Optimisation problem

3.A.1 Rich households problem

$$\mathcal{L} = \underset{c_{r,t},b_{r,t},m_{r,t}}{Max} \sum_{t=0}^{\infty} \beta^t \left(\left\{ \frac{C_{r,t}^{1-\sigma}}{1-\sigma} + \frac{(m_{r,t})^{1-\eta}}{1-\eta} - \chi_n \frac{(N_{r,t})^{1+\varphi}}{1+\varphi} \right\} + \lambda_t \left[w_t N_{r,t} + \left(\frac{m_{r,t-1} + R_{t-1} b_{r,t-1}}{\Pi_t} \right) - C_{r,t} - m_{r,t} - b_{r,t} \right] \right) \tag{3.37}$$

F.o.C

$$\frac{\partial \mathcal{L}}{\partial C_{r,t}} : \quad C_{r,t}^{-\sigma} = \lambda_t \tag{3.38}$$

$$\frac{\partial \mathcal{L}}{\partial N_{r,t}} : \quad \chi_n N_{r,t}^{\varphi} = w_t \lambda_t \tag{3.39}$$

$$\frac{\partial \mathcal{L}}{\partial m_{r,t}} : \quad m_{r,t}^{-\eta} + \frac{\beta \lambda_{t+1}}{\Pi_{t+1}} = \lambda_t \tag{3.40}$$

$$\frac{\partial \mathcal{L}}{\partial b_{r,t}} : \quad \frac{\lambda_{t+1} \beta R_t}{\Pi_{t+1}} = \lambda_t \tag{3.41}$$

Substitute equation (3.38) into (3.41) leads to Euler equation

$$C_{r,t}^{-\sigma} = C_{r,t+1}^{-\sigma} \beta (R_t / \Pi_{t+1}) \tag{3.42}$$

$$\frac{1}{R_t} = \frac{1}{1+i_t} \equiv E_t Q_{t,t+1}$$ [15]

$$\hat{c}_{r,t} = \hat{c}_{r,t+1} - \frac{1}{\sigma} \hat{r}_t$$

Substitute equation (3.38) by combining into (3.40) and (3.41) real demand for money,

$$C_{r,t}^{-\sigma} = \frac{C_{r,t}^{-\sigma}}{R_t} + m_{r,t}^{-\eta} \tag{3.43}$$

$$m_{r,t}^{-\eta} = C_{r,t}^{-\sigma} - \frac{C_{r,t}^{-\sigma}}{R_t}$$

$$m_{r,t}^{\eta} = C_{r,t}^{\sigma}\Big(\frac{1+i_t}{i_t}\Big)$$

$$\hat{m}_{r,t} = \frac{1}{\eta}\big(\sigma\hat{c}_{r,t} - \zeta\hat{i}_t\big) \tag{3.44}$$

Optimal condition for labor supply in the rural is given by substituting (3.38) to (3.39)

$$\frac{W_t}{P_t} = \chi_n \frac{N_{r,t}^{\psi}}{C_{r,t}^{-\sigma}}$$

$$\frac{W_t}{P_t} = \chi_n (N_{r,t})^{\psi} C_{r,t}^{\sigma}$$

$$\hat{w}_t = \psi\hat{n}_{r,t} + \sigma\hat{c}_{r,t} \tag{3.45}$$

3.A.2 Poor households

$$\begin{aligned}\mathcal{L} \quad = \quad & \underset{c_{p,t},b_{p,t},m_{p,t}}{Max} \sum_{t=0}^{\infty} \beta^t \left(\left\{ \frac{C_{p,t}^{1-\sigma}}{1-\sigma} + \frac{(m_{p,t})^{1-\eta}}{1-\eta} - \chi_n \frac{(N_{p,t})^{1+\varphi}}{1+\varphi} \right\} + \right. \\ & \left. \lambda_t \left[w_t N_{p,t} + \left(\frac{m_{p,t-1} + R_{t-1} b_{r,t-1}}{\Pi_t} \right) - C_{p,t} - m_{p,t} - b_{p,t} - AC_{p,t} \right] \right)\end{aligned} \tag{3.46}$$

[15] Stochastic discount factor

First order conditions

$$\frac{\partial \mathcal{L}}{\partial C_{p,t}} : \quad C_{p,t}^{-\sigma} = \lambda_t \tag{3.47}$$

$$\frac{\partial \mathcal{L}}{\partial N_{p,t}} : \quad \chi_n N_{p,t}^{\varphi} = w_t \lambda_t \tag{3.48}$$

$$\frac{\partial \mathcal{L}}{\partial m_{p,t}} : \quad m_{p,t}^{-\eta} + \frac{\beta \lambda_{t+1}}{\Pi_{t+1}} = \lambda_t \tag{3.49}$$

$$\frac{\partial \mathcal{L}}{\partial b_{p,t}} : \quad \frac{\lambda_{t+1} \beta R_t}{\Pi_{t+1}(1 + \Psi(b_{p,t} - b))} = \lambda_t \tag{3.50}$$

Substitute equation (3.47) into (3.50) leads to Euler equation

$$C_{p,t}^{-\sigma} = C_{p,t+1}^{-\sigma} \beta (R_t / \pi_{t+1}) [1 + \Psi(b_{p,t} - b)]^{-1} \tag{3.51}$$

$$\hat{c}_{p,t} = \hat{c}_{p,t+1} - \frac{1}{\sigma} \hat{r}_t + \Psi \tilde{b}_t^r$$

Substitute equation (3.47) into the combination of (3.49) and (3.50) real demand for money,

$$C_{p,t}^{-\sigma} = \frac{C_{p,t}^{-\sigma}}{R_t} [1 + \Psi(b_{p,t} - b)] + m_{p,t}^{-\eta}$$

$$m_{p,t}^{-\eta} = C_{p,t}^{-\sigma} - \frac{C_{p,t}^{-\sigma}}{R_t} [1 + \Psi(b_{p,t} - b)]$$

$$\frac{C_{p,t}^{\sigma}}{m_{p,t}^{\eta}} = 1 - \frac{1}{R_t} [1 + \Psi(b_{p,t} - b)] \tag{3.52}$$

$$\hat{m}_t^r = \frac{1}{\eta} \left(\sigma \hat{c}_{r,t} - \zeta \hat{i}_t \right) + \Psi \tilde{b}_t^r]$$

Optimal condition for labor supply in the rural is given by substituting (3.47) to (3.48)

$$\frac{W_t}{P_t} = \chi_n \frac{N_{p,t}^{\psi}}{C_{p,t}^{-\sigma}}$$

$$\frac{W_t}{P_t} = \chi_n (N_{p,t})^{\psi} C_{p,t}^{\sigma}$$

$$\hat{w}_t = \psi \hat{n}_{p,t} + \sigma \hat{c}_{p,t} \tag{3.53}$$

3.A.3 Philips Curve

The firm which re-optimizes in period t will choose the price P_t* that maximizes current market value of the profits generated while that price remains effective.

$$\underset{P_t^*}{Max}\ E_t \sum_{k=0}^{\infty} \omega^k Q_{t,t+k}\Big[P_t^*(i)Y_{t+k}(i) - TC_{t+k}(i)\big(Y_{t+k}(i)\big)\Big]$$
$$s.t \tag{3.54}$$
$$Y_{t+k}(i) = \left(\frac{P_t^*(i)}{P_{t+k}}\right)^{-\epsilon} C_{t+k}$$

Where $Y_{t+k}(i)$ is the firm's output in $t+k$ that adjusts price in t, $TC_{t+k}(i)\big(Y_{t+k}\big)$ is the firm's total cost in period $t+k$ as the functions of its output and stock holder's stochastic discounting factor is given by the $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma}$.

The unconstrained optimal choice of P_t^* [16] is

$$\mathcal{L} = \sum_{k=0}^{\infty} \omega^k E_t \left\{ \beta^k \Big(\frac{C_{t+k}}{C_t}\Big)^{-\sigma} \left[P_t^* \Big(\frac{P_t^*}{P_{t+k}}\Big)^{-\epsilon} C_{t+k} - TC_{t+k}(i) \left(\left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k} \right) \right] \right\}$$

First order condition :

$$\frac{\partial \mathcal{L}_t}{\partial P_t^*} = \sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} \left[(1-\epsilon) \Big(\frac{P_t^*}{P_{t+k}}\Big)^{-\epsilon} C_{t+k} + \epsilon M C_{t+k} \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon-1} \frac{C_{t+k}}{P_{t+k}} \right] \right\} = 0$$
$$\sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} \Big(\frac{P_t^*}{P_{t+k}}\Big)^{-\epsilon} C_{t+k} \right\} = \frac{\epsilon}{\epsilon - 1} \sum_{k=0}^{\infty} \omega^k E_t \left\{ Q_{t,t+k} M C_{t+k} \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon-1} \frac{C_{t+k}}{P_{t+k}} \right\}$$

[16] The optimal price is assumed to be chosen by all the firms that adjust their price at t, thus $P_t^*(i)$ is replaced by P_t^* for the rest of derivations

$$\sum_{k=0}^{\infty}\omega^k E_t\left\{Q_{t,t+k}Y_{t+k}(i)\right\} = \frac{\epsilon}{\epsilon-1}\sum_{k=0}^{\infty}\omega^k E_t\left\{Q_{t,t+k}MC_{t+k}\frac{Y_{t+k}(i)}{P_t^*}\right\}$$

$$\sum_{k=0}^{\infty}\omega^k E_t\left\{Q_{t,t+k}(i)P_t^*\left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon}C_{t+k}\right\} = \frac{\epsilon}{\epsilon-1}\sum_{k=0}^{\infty}\omega^k E_t\left\{Q_{t,t+k}MC_{t+k}\left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon}C_{t+k}\right\}$$

$$P_t^{*,1-\epsilon}(C_t)^{\sigma}\sum_{k=0}^{\infty}Q^k E_t\Big(\beta^k(C_{t+k}^{1-\sigma}P_{t+k}^{\epsilon}\Big) = \frac{\epsilon}{\epsilon-1}P_t^{*,-\epsilon}(C_t)^{\sigma}\sum_{k=0}^{\infty}\omega^k E_t\Big(\beta^k MC_{t+k}C_{t+k}^{1-\sigma}P_{t+k}^{\epsilon}\Big)$$

Divide both sides by P_tP_{t+k} to get optimal real price and future real marginal costs [17]

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{\epsilon-1}\frac{E_t\sum_{k=0}^{\infty}\omega^k\beta^k Mc_{t+k}(C_{t+k})^{1-\sigma}\left(\frac{P_{t+k}}{P_t}\right)^{\epsilon}}{E_t\sum_{k=0}^{\infty}\omega^k\beta^k(C_{t+k})^{1-\sigma}\left(\frac{P_{t+k}}{P_t}\right)^{\epsilon-1}} \tag{3.55}$$

Under flexible prices settings when the value of $\omega_t = 0$, (3.55) becomes

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{\epsilon-1}\frac{\omega^0\beta^0 MC_t(C_t)^{1-\sigma}(1)^{\epsilon}}{\omega^0\beta^0(C_t)^{1-\sigma}(1)^{\epsilon-1}} = \frac{\epsilon}{\epsilon-1}Mc_t \tag{3.56}$$

In a zero inflation steady state $\Pi_t = \frac{P_t^*}{P_{t-1}} = \frac{P^*}{P} = 1$ and letting $\mathcal{Z}_t$ being relative price $\frac{P_t^*}{P_t}$ and $\mu = \frac{\epsilon}{1-\epsilon}$. In the flexible price equilibrium the relative optimal price can be written as $\mathcal{Z}_t = \mu Mc_t = 1$

The law of motion of aggreate price is given by

$$\begin{aligned} P_t^{1-\epsilon} =&(1-\omega)(P_t^*)^{1-\epsilon} + \omega P_{t-1}^{1-\epsilon} \\ 1 =&(1-\omega)(\mathcal{Z}_t)^{1-\epsilon} + \omega\left(\frac{P_{t-1}}{P_t}\right)^{1-\epsilon} \end{aligned}$$

By taking first order Taylor expansion in a zero inflation steady state

$$\hat{z}_t = \left(\frac{\omega}{1-\omega}\right)\Pi_t \tag{3.57}$$

[17] MC_t stands for nominal marginal cost while Mc_t is real marginal cost.

Approximating (3.55) by first order Taylor expansion

$$\mathcal{Z}_t\left[E_t\sum_{k=0}^{\infty}\omega^k\beta^k(C_{t+k})^{1-\sigma}\Big(\frac{P_{t+k}}{P_t}\Big)^{\epsilon-1}\right]=\mu\left[E_t\sum_{k=0}^{\infty}\omega^k\beta^k Mc_{t+k}(C_{t+k})^{1-\sigma}\Big(\frac{P_{t+k}}{P_t}\Big)^{\epsilon}\right]$$

Left hand side (LHS)

$$\Big(\frac{C^{1-\sigma}}{1-\omega\beta}\Big)+\Big(\frac{C^{1-\sigma}}{1-\omega\beta}\Big)\hat{z}_t+C^{1-\sigma}\sum_{k=0}^{\infty}\omega^k\beta^k\Big((1-\sigma)E_t\hat{C}_{t+k}+(1-\epsilon)(E_t\hat{P}_{t+k})-\hat{P}_t\Big)$$

Right hand side (RHS)

$$\mu\left[Mc\Big(\frac{C^{1-\sigma}}{1-\omega\beta}\Big)+McC^{1-\sigma}\sum_{k=0}^{\infty}\omega^k\beta^k\Big(E_t\hat{M}c_{t+k}+(1-\sigma)E_t\hat{C}_{t+k}+\epsilon(E_t\hat{P}_{t+k}-\hat{P}_t\Big)\right]$$

Taking the two RHS and LHS with the condition $\mu Mc_t = 1$

$$\begin{aligned}
\frac{\hat{z}_t}{1-\omega\beta}+\sum_{k=0}^{\infty}\omega^k\beta^k\Big((1-\sigma)E_t\hat{C}_{t+k}+(1-\epsilon)(E_t\hat{P}_{t+k})-\hat{P}_t)\Big)\\
=\sum_{k=0}^{\infty}\omega^k\beta^k\Big(E_t\hat{M}c_{t+k}+(1-\sigma)E_t\hat{C}_{t+k}+\epsilon(E_t\hat{P}_{t+k}-\hat{P}_t)\Big)\\
=\frac{\hat{z}_t}{1-\omega\beta}=\sum_{k=0}^{\infty}\omega^k\beta^k\Big(E_t\hat{M}c_{t+k}+E_t\hat{P}_{t+k}-\hat{P}_t\Big)
\end{aligned}$$

By adding $\hat{P}_t$ both sides;

$$\begin{aligned}
\hat{z}_t+\hat{P}_t&=(1-\omega\beta)\sum_{k=0}^{\infty}\omega^k\beta^k\Big(E_t\hat{M}c_t+E_t\hat{P}_{t+k}\Big)\\
\hat{z}_t+\hat{P}_t&=(1-\omega\beta)(\hat{M}c_t+\hat{P}_t)\\
\hat{z}_{t+1}+\hat{P}_{t+1}&=(1-\omega\beta)(\hat{M}c_{t+1}+\hat{P}_{t+1})\\
\hat{z}_t+\hat{P}_t&=(1-\omega\beta)(\hat{M}c_t+\hat{P}_t)+\omega\beta(1-\omega\beta)(\hat{M}C_{t+1}+\hat{P}_{t+1})\\
\hat{z}_t+\hat{P}_t&=(1-\omega\beta)(\hat{M}c_t+\hat{P}_t)+\omega\beta(\hat{z}_{t+1}+\hat{P}_{t+1})\\
\hat{z}_t&=(1-\omega\beta)\hat{M}c_t+\omega\beta(\hat{z}_{t+1}+\hat{P}_{t+k}-\hat{P}_t)\\
&=(1-\omega\beta)\hat{M}c_t+\omega\beta(\hat{z}_{t+1}+\Pi_{t+k}) \qquad (3.58)
\end{aligned}$$

Combining (3.58) and (3.57)

$$
\begin{aligned}
\left(\frac{\omega}{1-\omega}\right)\Pi_t &= (1-\omega\beta)\hat{M}c_t + \omega\beta(E_t\hat{z}_{t+1} + E_t\Pi_{t+k}) \\
&= (1-\omega\beta)\hat{M}c_t + \omega\beta\left[\left(\frac{\omega}{1-\omega}\right)E_t\Pi_{t+k} + E_t\Pi_{t+k}\right] \\
&= (1-\omega\beta)\hat{M}c_t + \left(\frac{\omega\beta}{1-\omega}\right)E_t\Pi_{t+k} \\
\Pi_t &= \beta\Pi_{t+k} + \frac{(1-\omega\beta)(1-\omega)}{\omega}\hat{M}c_t \\
\Pi_t &= \beta\Pi_{t+k} + \tilde{\kappa}_j\hat{M}c_t \qquad (3.59)
\end{aligned}
$$

where $\tilde{\kappa} = \frac{(1-\omega\beta)(1-\omega)}{\omega}$

Appendix 3.B Supplementary Figures

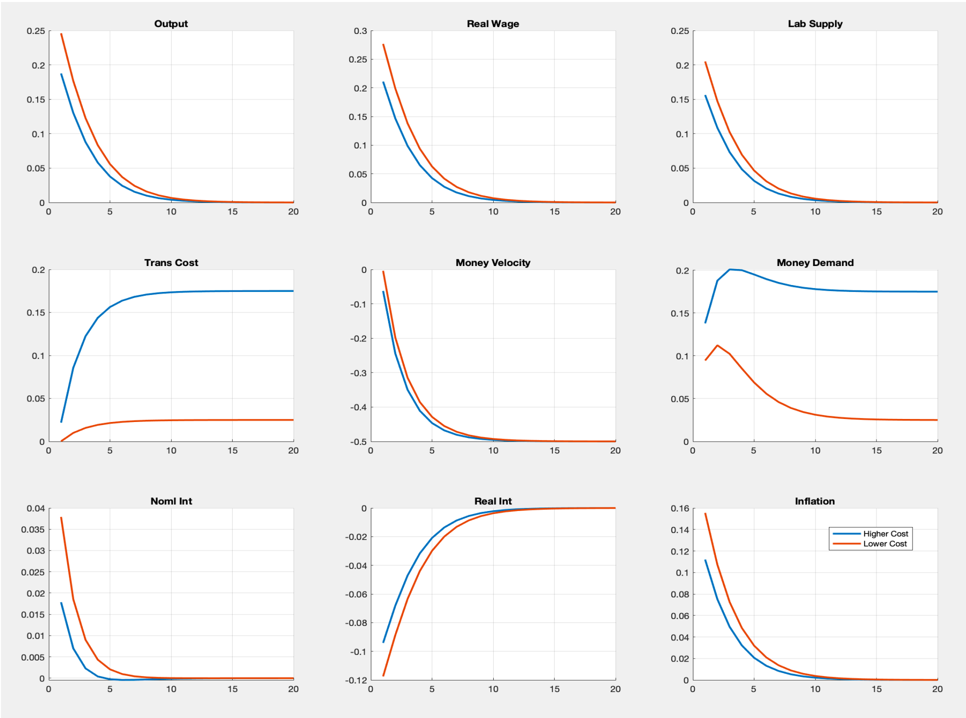

Figure 3.B.1: RANK Impulse Response Function to Monetary Policy Shock

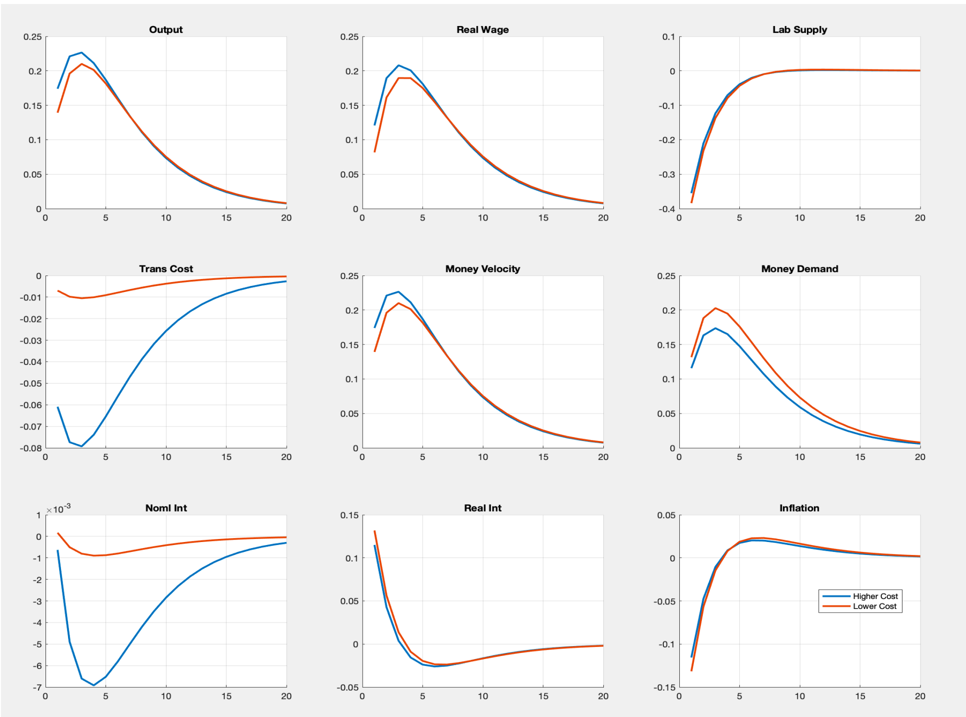

Figure 3.B.2: RANK Impulse Response Function to TFP Shock

Chapter 4

Financial Technology Role in Tanzania's Monetary Policy: Estimated MS-DSGE Models

4.1 Introduction

The previous chapter: 3, introduced a constant parameter two agent DSGE model, which is based on findings in Chapter: 2, which suggests presence of improvement signs in monetary policy transmission in Tanzania. Which is associated by gains from the increase in financial inclusion resulted from the adoption of FinTech.

The model simulations show that the monetary policy is getting stronger when there is a decrease in transaction cost. In the recent past, it has been observed that there is an increase in the number of users of the various new financial products in the system and the most popular ones are Mobile money, Mobile banking, Agent banking, and Internet banking of which their adoption has lead to a substantial decrease in transaction costs and decrease in the number of the unbanked population.

This chapter fits the model in Chapter: 3, employing Tanzania data, to establish the premises that FinTech and its enhancement of financial inclusion that has increased money velocity and multiplier coupled with a reduction in transaction costs have made monetary policy transmission mechanism to become more effective.

The nature of Tanzania's economy has in common most of the features a developing economy is characterized with. The larger size of her population living in the rural area is primarily engaging in agricultural activities and also most of the economic activities being informal. Because of this heterogeneity is of vital importance to employ a model which can at least better reflect the realities on the ground.

In that regard, a prototype model of the two-agent New Keynesian (TANK) model introduced by t introduced by Gali et al. (2004) and Bilbiie (2008) is adopted. The original model features limited asset market participation (LAMP) whereby the one agent is Ricardian and unconstrained while the other agent is non-Ricardian by being subsistence acting in Hand-to-Mouth fashion.

TANK models have become very popular recently, from the original model Cantore and Freund (2020), modified the model by incorporating capitalists and workers who are all unconstrained but capitalists do not work. The approach adopted in this paper is of a poor and rich household agent. Where poor households can save in bonds subject to portfolio adjustment costs. While the rich households, save in bonds without portfolio adjustment costs, also, are the owners of economy's firms and thus they receive the dividend. Further, both rich and poor households are subject to transaction costs with switching parameters[1] that are controlled by the Markov process.

Introducing regime switching in the TANK model allow to explore the possibility of identifying the structural change which has been brought by FinTech. Since the previous chapters have shown that there is some degree of pieces of evidence that the effectiveness of monetary policy can be attributed to the enhanced financial inclusion. The switching part will help to solidify this argument by identifying the switching direction and the time of regime change. Which can further be matched with the timing of the massive adoption of FinTech products in Tanzania.

[1] In this model the switching parameters will be transaction cost and portfolio adjustment cost

4.2 Literature Review

Regime switching DSGE models have proved to be a useful tool in modern macroeconomics. This is because economies undergo different structural changes that are often associated with fundamental changes of inter-linkages among different economic variables. However, the regime-switching concept is not particularly new, in the literature, several works have explored this concept like changes in changes in behavioral parameters, heteroscedasticity, and high and low regimes, Melino and Yang (2003) Sims and Zha (2006) , Leeper and Zha (2003) and Lubik and Schorfheide (2007).

Different sets of tools have been developed to solve these types of models because of their nature of nonlinear that involve estimation of parameters and unobserved variables can be computationally costly. This includes tools for finding nonlinear solutions to nonlinear regime-switching models with rational expectations by Alstadheim et al. (2013), Binning and Maih (2015) and Gerdrup et al. (2016). Efficient Perturbation Methods for Solving regime-switching DSGE Models that allow transition probabilities to be endogenous and for agents to react to anticipated events Maih (2015). This paper will employ this technique by applying these algorithms which are implemented in the RISE toolbox.

Choi and Hur (2015) estimated Markov-switching DSGE model for Korean data between 1976 to 2013, which allows a switch in the monetary policy rule coefficients and the shock volatility. The results show that the model was able to identify regime shift in monetary policy, whereby the policy was relatively strong to react to inflation compared to output after they adopted inflation targeting which was a different case for the regime before the adoption of the inflation target. This implies inflation targeting contributed to a sharp reduction in the level as well as the volatility of inflation. Also regime switch model fits well the Korean data compared to the constant parameter model

In determining how crucial regime inclusion of regime-switching is in monetary policy analysis and forecasting for DSGE models Anguyo et al. (2020), employed this technique in their study. Their model considered the heterogeneous agents in the household which is relatively an accurate way of describing an economy in a low-income country like Uganda, by allowing switching in monetary policy rule and other cases allowing both monetary policy rule and the volatility of the shocks are switching. The finding shows there is evidence that the model parameters have changed in the course of the two regimes, reflecting the dovish and hawkish policy responses. Also over certain horizons, the forecasting performance of the regime-switching models proved to be relatively superior compared to the constant parameter model.

Bjørnland et al. (2018) used a Markov Switching Rational Expectation New Keynesian model in analyzing oil price volatility role in reducing macroeconomic instability in the US considering the timing of the Great Moderation sources of changes in macroeconomic variables volatility. The findings show the US monetary policy, volatility in oil price shock, and US shock have switched regimes over time. Further results indicate the reduced volatility in the US macroeconomic variables is not associated with the declining oil price volatility albeit oil is a relevant source of intermittent macroeconomic fluctuations. Also, the decline in the volatility of structural macroeconomic shocks that is estimated to occur in 1984/1985 is the most important factor in reducing macroeconomic variability.

Liu and Mumtaz (2011), used Markov switching open economy dynamic stochastic general equilibrium(DSGE) model in probing the possibility of shifts in the UK economy. The finding shows its evident that the deep structural parameters have changed over the study sample from 1970 to 2009. Estimations suggest the policy structural parameters in Taylor rule provides the best empirical fit to the UK data if the switching is allowed. Furthermore, results suggest that the change in the policy rule coupled with lower volatility in the structural shocks played an important role in determining UK's macroeconomic performance.

In modeling and estimating the Zero Lower Bound(ZLB) in a simple New Keynesian model, Binning and Maih (2016), incorporated regime switches in their study by allowing for time preference shock, productivity growth rate, and the steady-state rate to switch between a normal steady-state and a ZLB steady state. The model was solved using a perturbation method and estimated using Bayesian methods with a regime-switching Kalman filter. The results show the US economy has and transitioned to a ZLB steady state that is characterized by precautionary savings behavior. Moreover, the finding indicates the expectations channel and the dynamics of the normal regime have a significant function in influencing agents' behavior while at the ZLB.

Schorfheide (2005), estimated New Keynesian monetary DSGE model with monetary policy that follows a rule which is subject to regime shifts. Their model is built under the assumptions of incomplete information about the state of monetary policy to the public and has to learn about the current regime. Their results are consistent with earlier studies that policy was marked by a shift to a high-inflation regime in the early 1970s. The presence of a learning mechanism affects the prediction of the effects of policy interventions. When there is prolonged intervention the agents are likely to interpret it as a shift to a new policy regime which ultimately leads to changes in the agents' expectation formation. Interventions that lead to small initial interest rate changes may be associated with much larger effects on output and inflation than under full information

The rest of this paper is organized in the following sections. Section 3 presents the Regime switching RANK and TANK model theoretical framework. Section 4, presents the Model solution and estimation method followed by results and discussions in Section 5, while Section 6 details provide policy implications, recommendations, and conclusion.

4.3 The Model Setup

4.3.1 Regime Switching RANK Model

A baseline model considers a Representative Agent New Keynesian (RANK) model, which assumes the economy consists of a continuum of infinitely lived households, a continuum of firms producing differentiated intermediate goods, monopolistic final good producing firms, and a central bank that determines monetary policy.

The model setup follows the same fashion as of Bilbiie (2008) and Cantore and Freund (2020) with (normalized) CES production function that has fixed costs, featuring staggering prices Calvo (1983).

4.3.1.1 Households

A representative household seeks to maximize money-in-utility (MIU) function, a model introduced by Sidrauski (1967). Which assumes that real money holdings increase the welfare of an economic agent thus, money can be incorporated directly into the household's utility function and then maximized;

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{(C_{t+k})^{1-\sigma}}{1-\sigma} + \frac{(M_{t+k}/P_{t+k})^{1-\eta}}{1-\eta} - \chi_n \frac{(N_{t+k})^{1+\varphi}}{1+\varphi} \right\} \tag{4.1}$$

Where C_t is the the consumption index of all individual goods i, such that $i \in [0,1]$, β_t is the period discount factor, N_t is labor, $\frac{M_t}{P_t}$ is real money balance and χ_n weights disutility from working hours;

subject to one period of budget constraint:

$$\int_0^1 P_t(i)C_t(i)di + B_t + M_t \leq N_t W_t + R_{t-1}B_{t-1} + M_{t-1} + D_t \tag{4.2}$$

Where R_t is the gross nominal interest rate, B_t is a stock of nominal bond held at the end of the period, W_t is nominal wage earned, D_t is the nominal profit received from firms, M_{t-1} and B_{t-1} is the amount of wealth held at the beginning of the period.

The representative household firstly has to decide how to allocate the consumption expenditure among different goods by maximizing consumption bundle C_t for any given level of expenditures, $P_tC_t = \int_0^1 P_t(i)C_t(i)$;

$$Max_{\ C_t(i)}\left(\int_0^1 C_t(i)^{\frac{\epsilon-1}{\epsilon}}di\right)di$$

$$subject\ to$$

$$P_tC_t \geq \int_0^1 P_t(i)C_t(i)$$

The problem leads to vector of demand equations and aggregate price index ;

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t \tag{4.3}$$

$$P_t = \left(\int_0^1 P_t(i)^{1-\epsilon}di\right)^{\frac{1}{1-\epsilon}} \tag{4.4}$$

Once the basket with a combination of each good and its price is known, then households decide optimal consumption/saving and amount of hours of work using (4.1) and (4.2). This problem leads to the following first-order conditions

$$\frac{1}{R_t} = \beta E_t\left[\frac{C_t^\sigma}{C_{t+1}^\sigma}\frac{P_t}{P_{t+1}}\right] \tag{4.5}$$

$$\frac{1}{R_t} = \frac{1}{1+i_t} \equiv E_tQ_{t,t+1}$$ [2]

$$\frac{W_t}{P_t} = \chi_n(N_t)^\varphi C_t \tag{4.6}$$

$$\left(\frac{M_t}{P_t}\right)^\eta = C_t^\sigma\left(\frac{1+i_t}{i_t}\right) \tag{4.7}$$

[2] Stochastic discount factor, implies, state-contingent assets price at t has uncertain payoff at $t+1$.

4.3.1.2 Firms

There are two types of firms, intermediate and final goods-producing firms. Intermediate firms employ labor as their only input to produce differentiated goods in a monopolistically competitive market with Calvo-type staggered pricing.

The representative final output producing firm uses input from intermediate firms which it bundles them to final goods using CES technology, with ϵ[3] denoting constant elasticity of substitution between the goods Y_i.

The final good producing firm maximises profit Subject to constant return to scale.

$$Y_t \leq \left(\int_0^1 Y_t(i)^{\frac{1-\epsilon}{\epsilon}} di \right)^{\frac{1}{1-\epsilon}}$$

$$\underset{Y_t(i)}{Max}\ \Pi_t = P_t \left[\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}} - \int_0^1 P_t(i) Y_t(i) di$$

The first order condition leads to downward sloping demand[4] curve for intermediate goods and aggregate price level.

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t, \quad P_t = \left(\int_0^1 P_t(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \tag{4.8}$$

Firm's Optimal Price Setting

Following Bilbiie (2008) formulation, the monopolistically competitive producers minimize cost $W_t N_t(i)$, given wage and the available state of technology which is linear in labor with fixed cost F[5]; $\quad Y_t(i) = A_t N_t(i) - F,\quad$ for $N_t(i) > F \quad$ otherwise $Y_t(i) = 0$

[3]The higher is ϵ the more substitutable these goods becomes (closer to perfect substitute goods).

[4]This can be interpreted as, a one percent increase in the relative price of good i results to a fall in the good's demand by ε percent

[5]The share of the fixed cost F in steady-state output governs the degree of increasing returns to scale

The Cost minimization problem leads us to the firm's marginal cost, $MC_t = W_t/A_t$.

$$\begin{aligned}\mathcal{L} = &\ \underset{N_t(i)}{Min} \Big(\frac{W_t}{P_t}\Big)N_t(i) + \varphi_t(Y_t - A_tN_t(i) + F)\\ \frac{\partial\mathcal{L}}{\partial N_t(i)} : &\ \frac{W_t}{P_t} = \varphi_t A_t\\ \varphi_t(i) = &\ \frac{W_t/P_t}{A_t} = Mc_t{}^{6}\end{aligned} \tag{4.9}$$

The Monopolistically competitive market structure gives the firms some degree of market power in setting their prices. Following Calvo (1983), to accommodate inflation persistence observed in real data, it's assumed that in each period some firms are not able to fully adjust their prices.

Firms that adjust their price are randomly selected, which is $1-\omega$ a fraction of all firms while on the other hand, the remaining ω indexes their price to previous-period $t-1$ inflation Senaj et al. (2010). The firms' probability of re-optimizing in any given period is independent of the time elapsed since it last reset its price. Therefore the average price in period t satisfies;

$$P_t^{1-\epsilon} = (1-\omega)(P_t^*)^{1-\epsilon} + \omega P_{t-1}^{1-\epsilon} \tag{4.10}$$

The firm which re-optimizes in period t will choose the price P_t^* that maximizes current market value of the profits generated while that price remains effective.

$$\begin{aligned}&\underset{P_t^*}{Max}\ E_t \sum_{k=0}^{\infty} \omega^k Q_{t,t+k}\Big[P_t^*(i)Y_{t+k}(i) - TC_{t+k}(i)\big(Y_{t+k}(i)\big)\Big]\\ &\quad \text{subject to}\\ &Y_{t+k}(i) = \left(\frac{P_t^*(i)}{P_{t+k}}\right)^{-\epsilon} C_{t+k},\end{aligned} \tag{4.11}$$

Where $Y_{t+k}(i)$ is the firm's output in $t+k$ that adjusts price in t, $TC_{t+k}(i)\big(Y_{t+k}\big)$ is

[6] Real marginal cost for all firms as they all face same liner production technology.

the firm's total cost in period $t+k$ as the functions of its output and stock holder's discounting factor $Q_{t,t+1}$. Solving (4.11) leads to the firms optimal relative price

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{k=0}^{\infty} \omega^k \beta^k Mc_{t+k} (C_{t+k})^{1-\sigma} \left(\frac{P_{t+k}}{P_t}\right)^{\epsilon}}{E_t \sum_{k=0}^{\infty} \omega^k \beta^k (C_{t+k})^{1-\sigma} \left(\frac{P_{t+k}}{P_t}\right)^{\epsilon-1}} \tag{4.12}$$

Under flexible prices settings when the value of $\omega_t = 0$, (4.12) becomes

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{\epsilon - 1} \frac{\omega^0 \beta^0 Mc_t (C_t)^{1-\sigma} (1)^{\epsilon}}{\omega^0 \beta^0 (C_t)^{1-\sigma} (1)^{\epsilon-1}} = \frac{\epsilon}{1-\epsilon} Mc_t \tag{4.13}$$

4.3.1.3 Money Velocity and Transaction Cost

This is the part which modifies the standard New-Keynesian model to accommodate the role played by FinTech products in shaping the stance of Monetary Policy in Tanzania since its inception. Studies show an inverse relationship between financial innovation and money demand. Dunne and Kasekende (2018), used Sub-Saharan Africa data to study this relationship, which concludes the premise. Judd and Scadding (1982), suggest financial innovations are associated with a shift in the amount of money desired to be held by individuals in the United States.

In this direction, by keeping the model simple we adopted money demand function proposed by Arrau et al. (1995), which is variant of Cagan model.[7] Money demand function proposed included transaction technology that could be interpreted as amount of resources spent in shopping activities.

$$\begin{aligned} h\left(\frac{m_t}{c_t^{\phi}}, \theta_t\right) &= -\frac{i_t}{1+i_t} \\ log(m_t) &= log(\theta_t) + log(c_t) - \alpha \frac{i_t}{1+i_t} \end{aligned}$$

State of transaction technology is represented by θ_t, thus a reduction in this

[7] The model describes individuals' demand for money and the evolution of inflation expectations over time, which implies that the velocity of money is increasing in the nominal interest rate.

parameter reduces the cost of transactions which is associated with (positive) financial innovation. By using the concept of demand for money as the amount of cash balance held at any point in time Laidler (1984).

The adoption of mobile money in Tanzania has Increased transaction demand for money thus increase in money velocity which is associated with a decrease in transaction cost[8] and inversely related to money demand, therefore we adopt the following modified money demand function:

$$h\left(\frac{m_t^{\eta}}{C_t^{\sigma}}, Tc_t(V_t)\right) = \frac{1+i_t}{i_t} + Tc_t \tag{4.14}$$

$$\text{Where} \quad Tc_t = V_t^{-\gamma}$$

Transaction cost Tc_t, is a decreasing function of velocity V_t for all values of $\gamma > 0$, which implies, the higher the value of γ the higher the money velocity enabled by advancement in financial architecture.

Regime switching is introduced in the model $S_t^{Tc} \in (High, Low)$: which allows parameter γ to follow an independent two-state Markov process, of low response or effective regime as $S_t^{Tc} = High$ and the high response or effective regime as $S_t^{Tc} = Low$. The process is characterized by constant transition probabilities of the following form:

$$P = \begin{bmatrix} 1 - P_{Tc}^{h,l} & P_{Tc}^{h,l} \\ P_{Tc}^{l,h} & 1 - P_{Tc}^{l,h} \end{bmatrix} \tag{4.15}$$

Where $P_{Tc}^{h,l}$, shows probability of switching from regime $High$ in period t to regime Low in period $t+1$, while $1 - P_{Tc}^{h,l}$ is probability of staying in regime $High$, and vice versa.

Transaction cost function in the real money balance becomes; $\quad Tc_t = V_t^{-\gamma(S_t^{Tc})}$

[8]This includes time spent to access banking services, and associated costs of cash deposit and withdraw as well as cost of credit since KYC is priority for mobile money.

4.3.1.4 Equilibrium and Aggregation

Market clearing in the goods markets implies that, the entire production is all consumed $Y_t(i) = C_t(i)$. Thus, using CES aggregation, total output becomes:

$$Y_t \equiv \left(\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \quad , \quad Y_t = C_t \tag{4.16}$$

Labor market clears when total household's labor supply equals to firms labor demand, such that $\int_0^1 N_t(i)di = N_t$. Therefore technology and demand function faced by firm implies that ; $A_t N_t(i) - F = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t$, when integrated over i.

$$\int_0^1 A_t N_t(i)di, -F = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t di \tag{4.17}$$

$$A_t \int_0^1 N_t(i)di - F = Y_t \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di$$

By defining new variable Δ_t

$$\Delta_t = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di \tag{4.18}$$

$$A_t N_t - F = Y_t \Delta_t \tag{4.19}$$

where Δ_t is price dispersion. Without pricing friction, every firm charges the same price thus Δ_t. But when $\Delta_t \geq 1$, results in output loss given A_t, Woodford (2011).

Representative intermediate firms' real profit is given by

$$D_t(i) = \frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t}{P_t} N_t(i)$$

Given aggregate output in (4.19), and real marginal cost in (4.9) the economy's total profit which goes to rich households who own the firm as dividend becomes,

$$D_t = Y_t - \frac{MC_t}{P_t} Y_t \Delta_t \tag{4.20}$$

4.3.1.5 Log-linear equilibrium and steady state

In analyzing the dynamics of the model we use its log-linear approximation around its non-stochastic steady state that is unique. The equilibrium conditions around this steady-state are indicated by small case letters showing the log-deviation of a variable from its steady-state, $\hat{x}_t = log(X_t/X) \simeq (X_t - X)/X$, $\hat{\pi}_t = log(P_t/P_{t-1})$ and $\hat{i}_t = i_t - i$.

In a zero inflation steady state $\Pi_t = \frac{P_t^*}{P_{t-1}} = \frac{P^*}{P} = 1$, let $\mathcal{Z}_t$ being optimal relative price $\frac{P_t^*}{P_t}$ and firm's desired average gross markup[9] $\mathcal{M} = \frac{\epsilon}{\epsilon - 1}$. In the flexible price equilibrium $\mathcal{Z}_t$ can be written as

$$\mathcal{Z}_t = \mathcal{M} Mc_t = 1$$

By taking first order Taylor expansion of (4.10) in a zero inflation steady state

$$\hat{z}_t = \left(\frac{\omega}{1-\omega}\right)\Pi_t$$

Approximation of (4.12) using First order Taylor expansion results to

$$\hat{z}_t = (1 - \omega\beta)\hat{M}c_t + \omega\beta(\hat{z}_{t+1} + \Pi_{t+k})$$

Combining these two conditions results to NK-Phillips Curve

$$\Pi_t = \beta\Pi_{t+k} + \tilde{\kappa}\hat{M}c_t \tag{4.21}$$

[9] The steady state net mark up $\mu = \frac{\epsilon}{\epsilon-1} - 1 = (\epsilon - 1)^{-1}$

4.3.2 Regime Switching TANK Models

The RANK model is extended to Two Agents New-Keynesian (TANK) model. These class of models have become popular recently since they allow heterogeneity which is more realistic than representative agent models.

While keeping the previous model assumption the same, we assume the two infinitely lived households differ with respect to two dimensions: i) the type of income they the have in their budget constraints ii) the type of market frictions the household is subjected to. The preferences of the households are the same and each of them chooses consumption, real money balance, assets holding and hours of labor supply.

4.3.2.1 Households

There is a continuum of households, who are indexed by j, such that $j \in [0, 1]$. It is assumed all households are Ricardian and they smooth consumption, by participating in markets for state-contingent securities. A fraction[10] α of household are termed as as poor, (p) have limited participation in financial markets since they participate at an extra cost. The remained $1-\alpha$ they don't face friction in accessing the financial markets and they are termed a rich (r) , thus $i = p$ if $j \in [0, 1-\alpha]$ and $i = r$ if $j \in [1-\alpha, 1]$.

Both households have similar preferences are characterized by CRRA, money-in-utility (MIU) function, maximized subject to a sequence of budget constraints which are different between poor and rich households, in solving inter-temporal allocation problem.

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{(C_{t+k})^{1-\sigma}}{1-\sigma} + \frac{(M_{i,t+k}/P_{t+k})^{1-\eta}}{1-\eta} - \chi_n \frac{(N_{i,t+k})^{1+\psi}}{1+\psi} \right\} \quad i \in (p, r)$$

[10] The fractions of rich and poor households are exogenously determined in the model.

4.3.2.1.1 Rich Households Optimal Allocation

It is assumed for the case of rich households don't incur transaction cost in accessing financial market since the financial infrastructures are well developed and the market are centered in the urban sector where they live. Also they are owners of Intermediate firms and thus receive profit in form of dividend. The utility maximization problem of the rich household becomes,

$$
\begin{aligned}
& Max \sum_{k=0}^{\infty} \beta^k U(C_{r,t+k}, M_{r,t+k}, N_{r,t+k}) \\
& \text{subject to} \qquad (4.22) \\
& B_{r,t} + \Omega_{r,t+1} V_t + M_t^r + P_t^r C_t^r \leq \Omega_{r,t}(V_t + P_t D_t) + N_t^r W_t^r + R_{t-1} B_{t-1}^r + M_{t-1}^r + D_t^r
\end{aligned}
$$

Where $\Omega_{r,t}$ are share holdings, D_t is shares' real dividend payoffs, V_t is shares' average market value at time t, $B_{r,t}$ and $M_{r,t}$ are the nominal value of the bond and money holding respectively at the end of period t.

Solution for (4.22) leads to the following optimal first order conditions at each date in each state.

Euler equation

$$
\begin{aligned}
\frac{1}{R_t} &= \beta E_t \left[\frac{C^{\sigma}_{r,t+1}}{C^{\sigma}_{r,t}} \frac{P_t}{P_{t+1}} \right] \\
\frac{1}{R_t} &= \frac{1}{1+i_t} \equiv E_t Q_{t,t+1} \qquad (4.23)
\end{aligned}
$$

Labor supply

$$
\frac{W_t}{P_t} = \chi_n (N_{r,t})^{\psi} C^{\sigma}_{r,t} \qquad (4.24)
$$

Real Money balance

$$
\left(\frac{M_{r,t}}{P_t}\right)^{\eta} = C^{\sigma}_{r,t}\left(\frac{1+i_t}{i_t}\right) \qquad (4.25)
$$

4.3.2.1.2 Poor households Optimal allocation

A significant number of household on $[0, \alpha]$ range, are poor and majority lives in the rural areas. Where the level of financial infrastructures are considerably inadequate, thus exist friction to access the financial markets. Schmitt-Grohé and Uribe (2003) the friction can be in form of a simple quadratic form, denoted by AC_t[11]. Rural households budget constraint is given by

$$B_{p,t} + P_t AC_t + M_{p,t} + P_t C_{p,t} = N_{p,t} W_t + R_{t-1} B_{p,t-1} + M_{p,t-1} \tag{4.26}$$
$$where \quad AC_t = \frac{\Psi}{2} \left[B^r_{p,t} - B_p \right]^2$$

Where B_p is the steady state level of bond holding, and Ψ is the portfolio adjustment cost. The adjustment costs affects the Euler equation through inter-temporal consumption choice. [12] Solving the households optimization problem of choosing bond, money holding and consumption leads to the following first order conditions;

Euler equation

$$\frac{1}{R_t} = \beta E_t \left[\frac{C^\sigma_{p,t+1}}{C^\sigma_{p,t}} \frac{P_t}{P_{t+1}} \right] (1 + \Psi(b_{p,t} - b_p))^{-1}$$
$$E_t(C^\sigma_{p,t+1}) = \beta r_t C^\sigma_{p,t} [1 + \Psi(b_{p,t} - b_p] \tag{4.27}$$

Labor supply

$$\frac{W_t}{P_t} = \chi_n (N_{p,t})^\psi C_{p,t} \tag{4.28}$$

Real Money balance

$$\left(\frac{M_{p,t}}{P_t} \right)^\eta = C^\sigma_{p,t} \left(\frac{1 + i_t}{i_t} \right) [1 + \Psi(b_{p,t} - b_p] \tag{4.29}$$

[11] AC Costs are paid in terms of output, and are non-zero at the steady-state, generating a non-zero demand for bonds with different maturities in the long-run

[12] As an increase in the cost of bonds trading reduces the sensitivity of wealth's accumulation to a variation of the interest rate as it becomes more costly to smooth consumption. when the parameter increases it becomes more costly for the households to access the financial markets.

4.3.2.2 Switch in Transaction and Adjustment Costs

Keeping the same argument in Section:4.3.1.3, the adoption of mobile money in Tanzania has increased transaction demand for money thus increase in money velocity. However, the extent of change has been different for both rich and poor households.

Mobile money has resulted in to decrease in transaction cost in terms of deposit and withdrawal fees as well as cost in participating in financial markets. This change in cost has been in favor of poor households since before the use of mobile it was more expensive for the poor to access financial services as compared to the rich. This makes the specification of the transaction cost function for rich, $Tc_{r,t} = V_t^{-\gamma_r}$ and $Tc_{p,t} = V_t^{-\gamma_p}$ for poor households.

To introduce regime switching in TANK model two different sets of assumption are made, and thus leads to two different models as follows:

Switch in Transaction (TANK1)

We introduced regime switching in the model $S_t^{Tc} \in (High, Low)$: which allows parameters γ_r, γ_p to follow an independent two-state Markov process, of low response or effective regime as $S_t^{Tc} = High$ and the high response or effective regime as $S_t^{Tc} = Low$. Thus real money balance functions are modified to:

$$\left(\frac{M_{p,t}}{P_t}\right)^{\eta} = C_{p,t}^{\sigma}\left(\frac{1+i_t}{i_t}\right)[1 + \Psi(b_{p,t} - b_p] + Tc_{p,t}(S_t^{Tc}) \tag{4.30}$$

$$\left(\frac{M_{r,t}}{P_t}\right)^{\eta} = C_{r,t}^{\sigma}\left(\frac{1+i_t}{i_t}\right) + Tc_{r,t}(S_t^{Tc}) \tag{4.31}$$

The two-state Markov process process is characterized with constant transition probabilities of the following form:

$$P = \begin{bmatrix} 1 - P_{Tc}^{h,l} & P_{Tc}^{h,l} \\ P_{Tc}^{l,h} & 1 - P_{Tc}^{l,h} \end{bmatrix} \tag{4.32}$$

Switch in Transaction and Adjustment Costs (TANK2)

In this version of the model regime switching in $S_t^{Ta} \in (High, Low)$ is introduced to allow parameters γ_r, γ_p and Ψ to follow the same[13] independent two-state Markov process, of low response or effective regime as $S_t^{Ta} = High$ and the high response or effective regime as $S_t^{Ta} = Low$. Thus real money balance functions are modified to:

$$\Big(\frac{M_{p,t}}{P_t}\Big)^{\eta} = C_{p,t}^{\sigma}\Big(\frac{1+i_t}{i_t}\Big)[1+\Psi(S_t^{Ta})(b_{p,t}-b_p] + Tc_{p,t}(S_t^{Ta}) \tag{4.33}$$

$$\Big(\frac{M_{r,t}}{P_t}\Big)^{\eta} = C_{r,t}^{\sigma}\Big(\frac{1+i_t}{i_t}\Big) + Tc_{r,t}(S_t^{Ta}) \tag{4.34}$$

The two-state Markov process process is characterized with constant transition probabilities of the following form:

$$P = \begin{bmatrix} 1-P_{Ta}^{h,l} & P_{Ta}^{h,l} \\ P_{Ta}^{l,h} & 1-P_{Ta}^{l,h} \end{bmatrix} \tag{4.35}$$

Where $P_{Ta}^{h,l}$, shows probability of switching from regime $High$ in period t to regime Low in period $t+1$, while $1-P_{Ta}^{h,l}$ is probability of staying in regime $High$.

4.3.2.3 Aggregation and accounting

Labor market clears when labor demand by all firms equal aggregate households labor supply and goods market clears when total consumption equal to individual composite demands consumption indexed over $\in [0,1]$

$$N_t = \alpha N_{p,t} + (1-\alpha)N_{r,t} = \int_0^1 N_t^j dj \tag{4.36}$$

$$C_t \equiv \alpha C_{p,t} + (1-\alpha)C_{r,t} = \int_0^1 C_t^j dj \tag{4.37}$$

[13] In order to economize on parameters and computational cost, identifying assumption is FinTech revolution which had doubled edged impact happened simultaneously

Clearing conditions in money markets:

$$M_t \equiv \int_0^1 M_t^j dj = \alpha M_{p,t} + (1-\alpha) M_{r,t} \tag{4.38}$$

$$Tc_t = \alpha Tc_{p,t} + (1-\alpha) Tc_{r,t} \tag{4.39}$$

$$B_t = \alpha B_{r,t} + (1-\alpha) B_{p,t} \quad B_t = 0 \tag{4.40}$$

4.3.2.4 Log-linear Equilibrium and Steady State

In a stationary equilibrium with zero inflation the gross interest rate is $R = \beta^{-1} \equiv 1 + r$. Equity market clearing implies that share holdings of each asset holder are $\Omega_{r,t+1} = \Omega_{r,t} = \Omega = \frac{1}{1-\lambda}$. Share of total profit to income is $D_Y = (\mu - F_Y)/(1+\mu)$ by assuming $\mu = (\varepsilon - 1)^{-1}$ and share of labor income to output is $WN/PY = (1+F_Y)/(1+\mu)$ where $F_Y \equiv F/Y$ is share of fixed cost to total output.

The equilibrium conditions around this steady state, are indicated by small case letters showing the log-deviation of a variable from its steady state, $\hat{x}_t = log(X_t/X) \simeq (X_t - X)/X$, $\hat{\pi}_t = log(P_t/P_{t-1})$, $\hat{i}_t = i_t - i$ and share of real profit to income $\tilde{d}_t = (D_t - D)/Y$,

RANK Model

Basic Representative Model with regime switching parameters

Table 4.1: RANK Model Summary.

Description	Equation
Euler Equation	$\hat{c}_t = \hat{c}_{t+1} - \hat{r}_t$
Labor Supply	$\hat{c}_t = \hat{w}_t - \varphi \hat{n}_t$
Real Marginal Cost	$\hat{mc}_t = \hat{w}_t - \hat{a}_t$
Phillips Curve	$\pi_t = \beta \pi_{t+1} + \tilde{\kappa} \hat{mc}_t$
Market Clearing	$\hat{c}_t = \hat{y}_t$
Production Function	$\hat{y}_t = (1+\mu)a_t + (1+\mu)\hat{n}_t$
Transaction Cost	$\hat{Tc}_t = -\gamma(S_t^{Tc})\hat{v}_t$
Real Money Balance	$\hat{m}_t = \frac{1}{\eta}\left(\sigma \hat{c}_t - \zeta \hat{i}_t + \hat{Tc}_t\right)$
Real Interest Rate	$\hat{r}_t = \hat{i}_t - \hat{\pi}_{t+1}$
Inflation	$\hat{\pi}_t = \hat{p}_t - \hat{p}_{t-1}$
Money Supply	$\hat{ms}_t = \hat{m}_t + \hat{p}_t$
Monetary Policy	$\hat{\lambda}_{m,t} = \hat{m}_t - \hat{m}_{t-1} + \hat{\pi}_t$
Money Velocity	$\hat{v}_t = \hat{c}_t - \hat{ms}_t$
Money Growth Process	$\hat{\lambda}_{m,t} = \rho_m \hat{\xi}_{m,t-1} + \hat{\varepsilon}_{m,t}$
TFP Schock Process	$\hat{a}_t = \rho_a \hat{a}_{t-1} + \hat{\xi}_{a,t}$

TANK1 Model

From the baseline TANK model, refer Table:3.1, the following changes are made to the System of model equations to accommodate fro the regime switching parameters.

Table 4.2: TANK1 Model Summary.

Description	Equation
Euler Equation R	$\hat{c}_{r,t} = \hat{c}_{r,t+1} - \hat{r}_t$
Euler Equation P	$\hat{c}_{p,t} = \hat{c}_{p,t+1} - \hat{r}_t + \Psi\tilde{b}_{p,t}$
Transaction Cost R	$\hat{T}c_{r,t} = -\gamma_r(S_t^{Tc})\hat{v}_t$
Transaction Cost P	$\hat{T}c_{p,t} = -\gamma_p(S_t^{Tc})\hat{v}_t$
Total Transaction Cost	$\hat{T}c_t = \alpha\hat{T}c_{p,t} + (1-\alpha)\hat{T}c_{r,t}$
Real Money Balance R	$\hat{m}_{r,t} = \frac{1}{\eta}\big(\sigma\hat{c}_{r,t} - \zeta\hat{i}_t + \hat{T}c_{r,t}\big)$
Real Money Balance P	$\hat{m}_{p,t} = \frac{1}{\eta}\big(\sigma\hat{c}_{p,t} - \zeta\hat{i}_t + \hat{T}c_{p,t} + \Psi\tilde{b}_{p,t}\big)$
Total Money Balance	$\hat{m}_t = \alpha\hat{m}_{p,t} + (1-\alpha)\hat{m}_{r,t}$

TANK2 Model

With references of Table:3.1, for TANK model, two state regime switching is introduced to allow parameters to vary across regimes.

Description	Equation
Euler Equation R	$\hat{c}_{r,t} = \hat{c}_{r,t+1} - \hat{r}_t$
Euler Equation P	$\hat{c}_{p,t} = \hat{c}_{p,t+1} - \hat{r}_t + \Psi(S_t^{Ta})\tilde{b}_{p,t}$
Transaction Cost R	$\hat{T}c_{r,t} = -\gamma_r(S_t^{Ta})\hat{v}_t$
Transaction Cost P	$\hat{T}c_{p,t} = -\gamma_p(S_t^{Ta})\hat{v}_t$
Total Transaction Cost	$\hat{T}c_t = \alpha\hat{T}c_{p,t} + (1-\alpha)\hat{T}c_{r,t}$
Real Money Balance R	$\hat{m}_{r,t} = \frac{1}{\eta}\big(\sigma\hat{c}_{r,t} - \zeta\hat{i}_t + \hat{T}c_{r,t}\big)$
Real Money Balance P	$\hat{m}_{p,t} = \frac{1}{\eta}\big(\sigma\hat{c}_{p,t} - \zeta\hat{i}_t + \hat{T}c_{p,t} + \Psi(S_t^{Ta})\tilde{b}_{p,t}\big)$
Total Money Balance	$\hat{m}_t = \alpha\hat{m}_{p,t} + (1-\alpha)\hat{m}_{r,t}$

Table 4.3: TANK2 Model Summary.

4.3.3 Monetary Authority

In this regard following Danthine and Kurmann (2004) Monetary authorities exogenously set the (net) growth rate of money $\lambda_{m,t}$, such that the supply of real balances evolves according to

$$m_t = (1 + \lambda_{m,t})m_{t-1}\frac{P_{t-1}}{P_t} \tag{4.41}$$

Where money growth rate follows an AR(1) process such that

$$\lambda_{m,t} = \rho_m \lambda_{m,t-1} + \xi_{m,t} \tag{4.42}$$

4.4 Model Solution, Data and Estimation

4.4.1 Data

The parameter estimations are based on quarterly data from the period 2005Q1 to 2020Q3 on three macroeconomic variables, which are GDP per capita, inflation rate, and nominal interest rate. Data sources for the variables used were based on data obtained from the Bank of Tanzania (BoT) and the National Bureau of Statistics (NBS).

Data transformation was done by taking the log of real GDP per capita, adjusting for seasonality, and estimating the output gap using the Hodrick-Prescott filter. The annual Inflation rate which is observed monthly is transformed to a quarterly rate by taking a 3-month simple average divided by 400. The same techniques were employed to annualized nominal interest rates to obtain quarterly rates.

4.4.2 The Model Solution

The parameters in the model are estimated using Bayesian methods by employing the RISE toolbox for Matlab, Maih (2015). Whereby the system equations are coded in a text file in such a way that is compatible with the RISE language.

To enable Bayesian estimations, the RISE toolbox takes the file containing the equations and automatically computes the perturbation solution, and transforms the system into state-space representation. In this estimation[14] we only solve the model in first-order approximation. As the fact that regimes are not observed as other model variables like transaction cost likelihood is computed by employing filtering algorithm. RISE collapses the updates in the filtering procedure this way is more computationally efficient.

4.4.3 Calibration

Table 4.1: Baseline Calibrated Parameters

Parameter	Description	Comment
$\beta = 0.98$	Subjective discount factor	Calculations from the data
$\varphi = 0.15$	Inverse of Frisch elasticity	Goldberg (2016)
$\eta = 1$	Real money balance preference	Galí (2008)
$\zeta = 4$	interest-elasticity of the demand for money	Galí (2008)
$\alpha = 0.72$	Share of Poor households	Calculations from the data
$\theta = 0.66$	Calvo price stickiness parameter	Prasad and Zhang (2015)
$R_{ss} = \beta^{-1}$	Steady state gross nominal interest rate	
$\epsilon = 10.0$	Elasticity of substitution among varieties	Woodford (2011)

[14]RISE is able to solve models to higher orders of approximation.

Parameter calibrated in model simulations in Chapter: 3, in Table: 3.1 are used in because of limitations to identify all of them in the data sample. However, with some exceptions, of the parameters which matters the most in exploring our subject will be estimated.

4.4.4 Prior distribution

According to An and Schorfheide (2007) a Bayesian estimation approach has three advantages over limited information approaches. First, Bayesian estimation is system based and uses all the information provided by the data by fitting the DSGE model to a vector of aggregate time series.

Prior distributions used incorporates additional information not included in the data into parameters estimates. Prior distributions may reflect subjective judgment, conventional wisdom, evidence from previous studies or results from micro-level data. However, estimated DSGE literature for emerging economies is very limited and is virtually in-existent for Tanzania.

4.5 Empirical Results

Fitting our model to Tanzanian data will help to identify some parameter which were previously calibrated and showed there is some degree of regime switch in monetary policy transmission mechanism. It is believed FinTech has accelerated financial inclusion and thus enhanced effectiveness of monetary policy transmission why significantly reducing transaction cost and portfolio adjustment costs.

4.5.1 Parameter estimates and regime probabilities

Parameter	Description	Distribution	Prior		Posterior	
			Mean	Std dev	Mean	Std dev
$P_{Tc}^{h,l}$	Transition probability (High-Low)	Beta	0.2	0.1	0.1328	0.0179
$P_{Tc}^{l,h}$	Transition probability (Low-High)	Beta	0.2	0.1	0.1062	0.0164
$\gamma(S_t^{Tc} = High)$	Transaction cost	Beta	0.35	0.12	0.3112	0.0940
$\gamma(S_t^{Tc} = Low)$	Transaction cost	Beta	0.05	0.05	0.0559	0.0101
σ	Degree of relative risk aversion	Gamma	1.7	0.5	0.3657	0.0841
ρ_z	Persistence of technology	Beta	0.79	0.1	0.6582	0.0787
ρ_m	Persistence of money growth	Beta	0.5	0.1 5	0.3007	0.0771
ρ_{is}	Persistence of supply shock	Beta	0.8	2.0	0.9219	0.0342
σ_z	Standard dev. of technology	Inv_Gamma	0.002	2.0	0.0279	0.0028
σ_m	Standard dev. of monetary policy	Inv_Gamma	0.065	2.0	0.0101	0.0044
$stderr_i$	Measurement err in interest rate	Inv_Gamma	0.004	0.1	0.0010	2.9256e-04

Table 4.1: Bayesian Estimation Results for RANK Model

Estimated Results from simple RANK model in Table: 4.1, shows the transition probability of transaction cost has shifted from being higher to lower for about 13 percent. Figure:4.1, show estimated parameter distribution which fits well the data, except high transaction Cost in regime 2 was not properly identified, which is likely data point point is not enough to identify it.

Transaction cost switching from higher to lower cost regime around end of 2013, and the change being influenced by monetary policy control variable. The results are consistent with the ones from structural and regime switching VAR models.

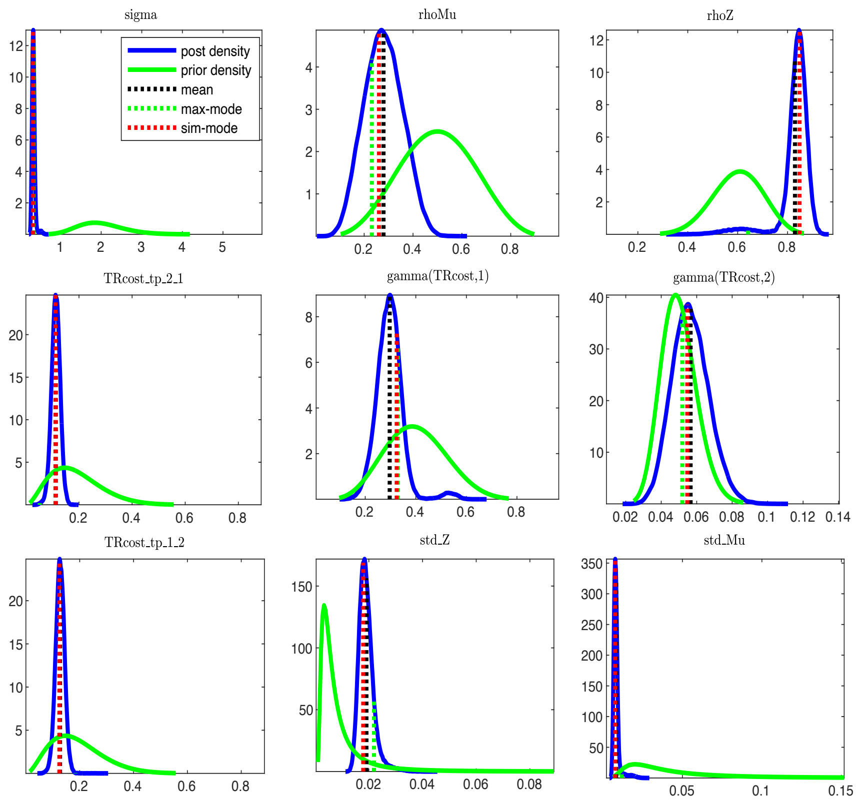

Figure 4.1: Prior and Posterior distribution for RANK Model

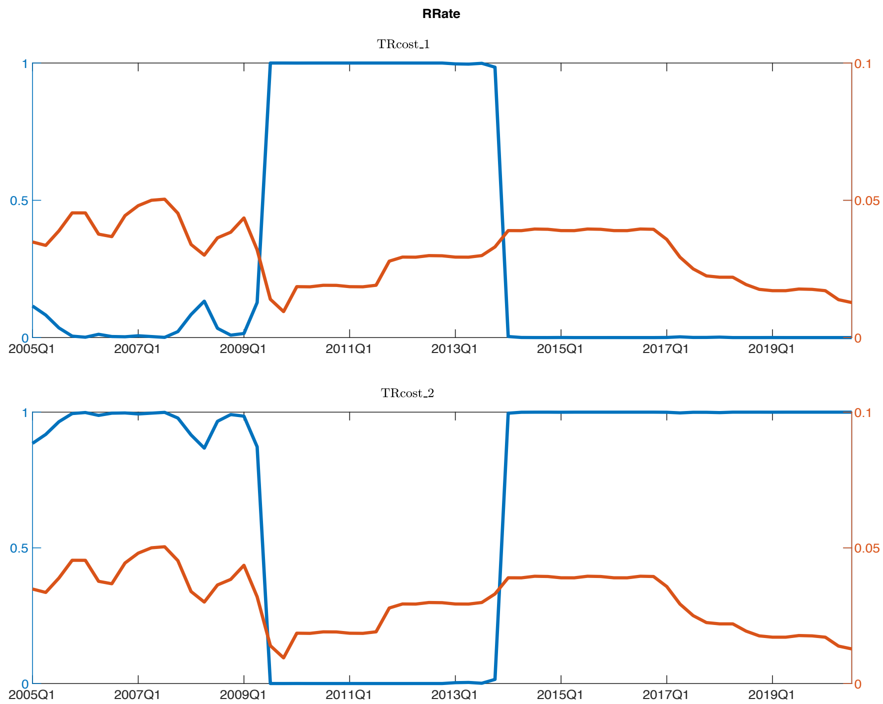

Figure 4.2: RANK Model Smoothed Regime Probabilities and Interest Rate

Parameter	Description	Distribution	Prior		Posterior	
			Mean	Std dev	Mean	Std dev
$P_{Tc}^{h,l}$	Transition probability (High-Low)	Beta	0.2	0.10	0.1012	0.0118
$P_{Tc}^{l,h}$	Transition probability (Low-High)	Beta	0.2	0.10	0.0989	0.0135
$\gamma_p(S_t^{Tc} = High)$	Rich hh. transaction cost	Beta	0.95	0.02	0.9434	0.0183
$\gamma_p(S_t^{Tc} = Low)$	Rich hh. transaction cost	Beta	0.55	0.15	0.8418	0.0365
$\gamma_r(S_t^{Tc} = High)$	Poor hh. transaction cost	Beta	0.35	0.12	0.3166	0.0753
$\gamma_r(S_t^{Tc} = Low)$	Poor hh. transaction cost	Beta	0.05	0.01	0.0493	0.0079
σ	Degree of relative risk aversion	Gamma	1.7	0.50	0.7775	0.0301
ρ_z	Persistence of technology	Beta	0.79	0.10	0.8758	0.0232
ρ_m	Persistence of money growth	Beta	0.5	0.20	0.4614	0.0441
ρ_{is}	Persistence of supply shock	Beta	0.7	0.20	0.7689	0.0185
σ_z	Standard dev. of technology	Inv_Gamma	0.002	2.0	0.0293	0.0026
σ_m	Standard dev. of monetary policy	Inv_Gamma	0.065	2.0	0.0237	0.0032
$stderr_i$	Measurement err in interest rate	Inv_Gamma	0.004	2.0	7.7123e-04	1.7817e-04

Table 4.2: Bayesian Estimation Results for TANK1 Model

The TANK1 model with transaction cost parameter switching from higher to lower regime, being controlled by the same process has fairly estimated parameter of interest. From Figure:4.3 posterior densities are well behaved and transition probability of switching from higher to lower cost is 12 percent yet the switch occurred. This signifies that the there has been some structural changes in the economy pin pointing the same timing in mid 2013, refer Figure:4.4.

However in the low cost regimes the cost parameter for the rich households and lower cost regimes for the poor households is not well identified. The results generally indicates the same phenomenon as in the RANK model, that means the model is robust enough but limited with data points used in the estimations.

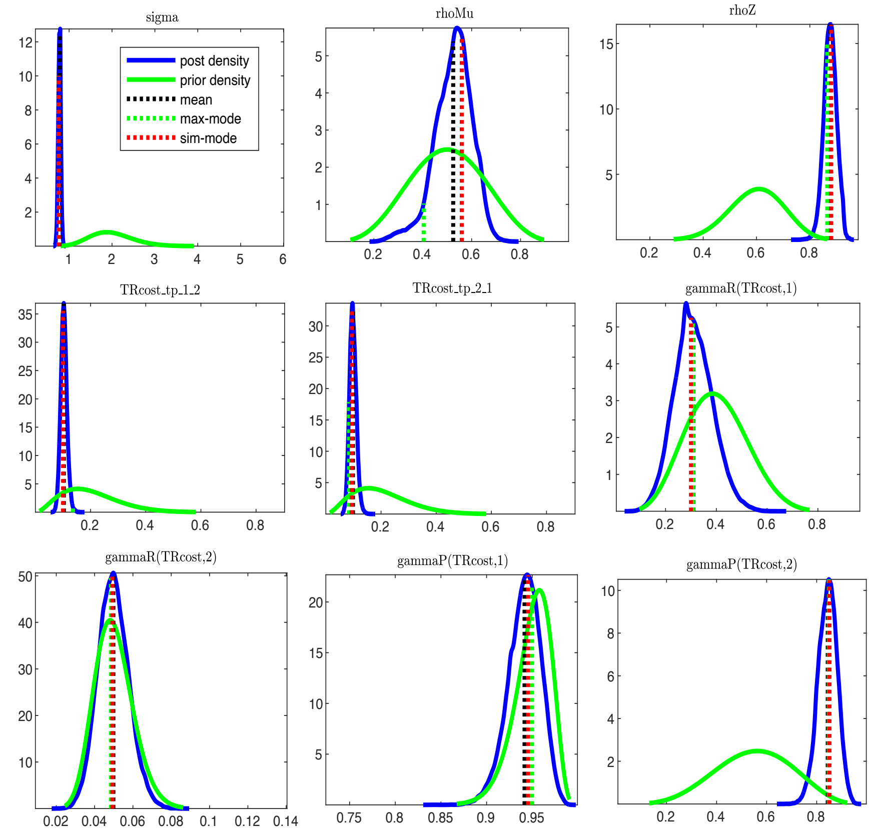

Figure 4.3: Prior and Posterior distribution for TANK1 Model

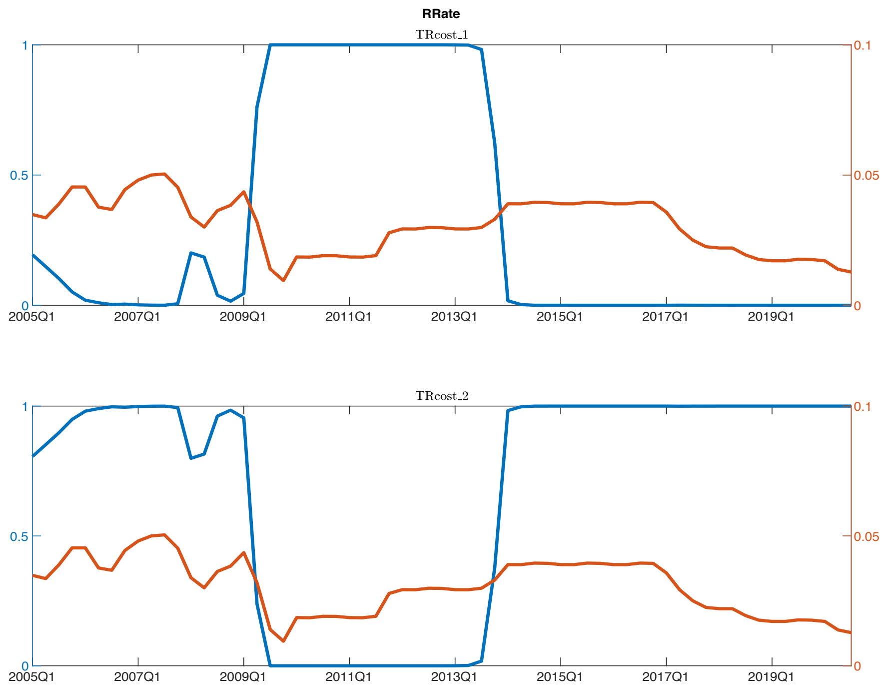

Figure 4.4: TANK1 Model Smoothed Regime Probabilities and Interest Rate

Parameter	Description	Distribution	Prior		Posterior	
			Mean	Std dev	Mean	Std dev
$P_{Ta}^{h,l}$	Transition probability (High-Low)	Beta	0.2	0.1	0.0986	0.0113
$P_{Ta}^{l,h}$	Transition probability (Low-High)	Beta	0.2	0.1	0.1042	0.0092
$\gamma_p(S_t^{Ta} = High)$	Rich hh. transaction cost	Beta	0.95	0.02	0.9503	0.0157
$\gamma_p(S_t^{Ta} = Low)$	Rich hh. transaction cost	Beta	0.55	0.15	0.8269	0.0249
$\gamma_r(S_t^{Ta} = High)$	Poor hh. transaction cost	Beta	0.35	0.12	0.2553	0.0367
$\gamma_r(S_t^{Ta} = Low)$	Poor hh. transaction cost	Beta	0.05	0.01	0.0455	0.0072
$\Psi(S_t^{Ta} = High)$	Poor hh. adjustment cost	Beta	0.25	0.12	0.1232	0.0363
$\Psi(S_t^{Ta} = Low)$	Poor hh. adjustment cost	Beta	0.0025	0.0015	0.0028	0.0012.
σ	Degree of relative risk aversion	Gamma	1.7	0.54	0.7015	0.0334
ρ_z	Persistence of technology	Beta	0.79	0.1	0.8237	0.0279
ρ_m	Persistence of money growth	Beta	0.5	0.15	0.4129	0.0606
ρ_{is}	Persistence of supply shock	Beta	0.8	0.1	0.7992	0.0120
σ_z	Standard dev. of technology	Inv_Gamma	0.002	2.0	0.0278	0.0023
σ_m	Standard dev. of monetary policy	Inv_Gamma	0.065	2.0	0.0204	0.0035
$stderr_i$	Measurement err in interest rate	Inv_Gamma	0.004	2.0	8.1634e-04	1.7823e-04

Table 4.3: Bayesian Estimation Results for TANK2 Model

In Table:4.3, are the results of the TANK2[15] model that allows for transaction cost and adjustment cost parameters to switch following the same two sate Markov process. Adjustment cost in lower regime and transaction cost in regime two for rich and regime one for poor are not well identified. The rest of the parameters well estimated which are similar results as previous RANK and TANK1 models.

Transition probability of switching from higher to lower transaction and adjustment cost all together is 9 percent, which occurred in mid 2013 being influenced by policy rate Figure:4.6. In this period there was a surge in number of people using mobile money, mobile banking and agent banking.

[15]Both transaction and adjustment cost switch using same process while TANK1 only transaction cost switches

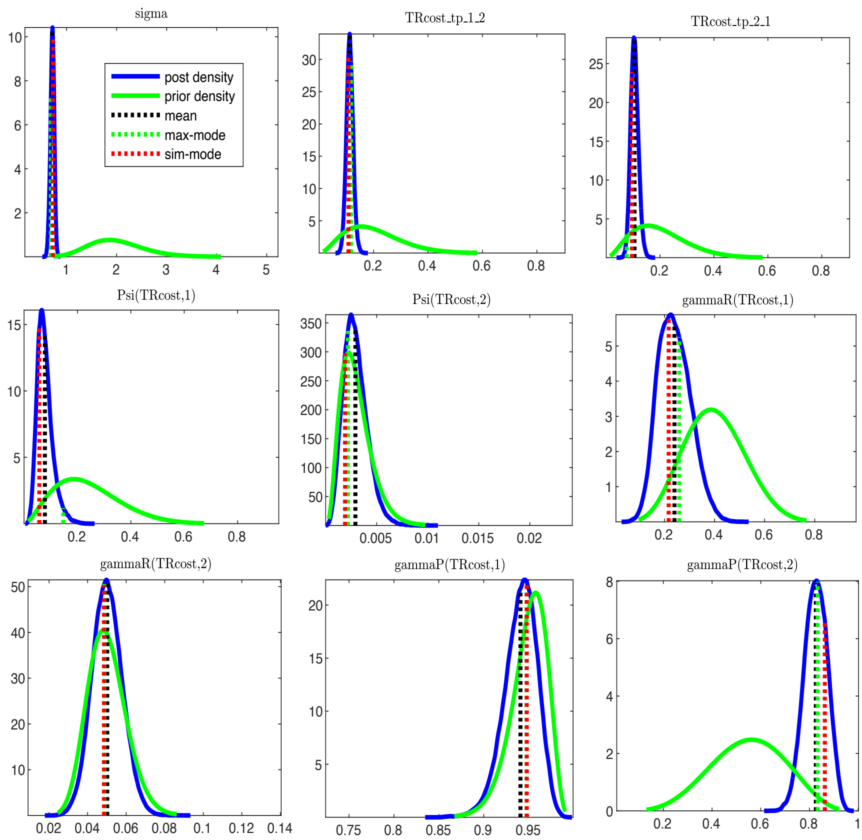

Figure 4.5: Prior and Posterior distribution for TANK2 Model

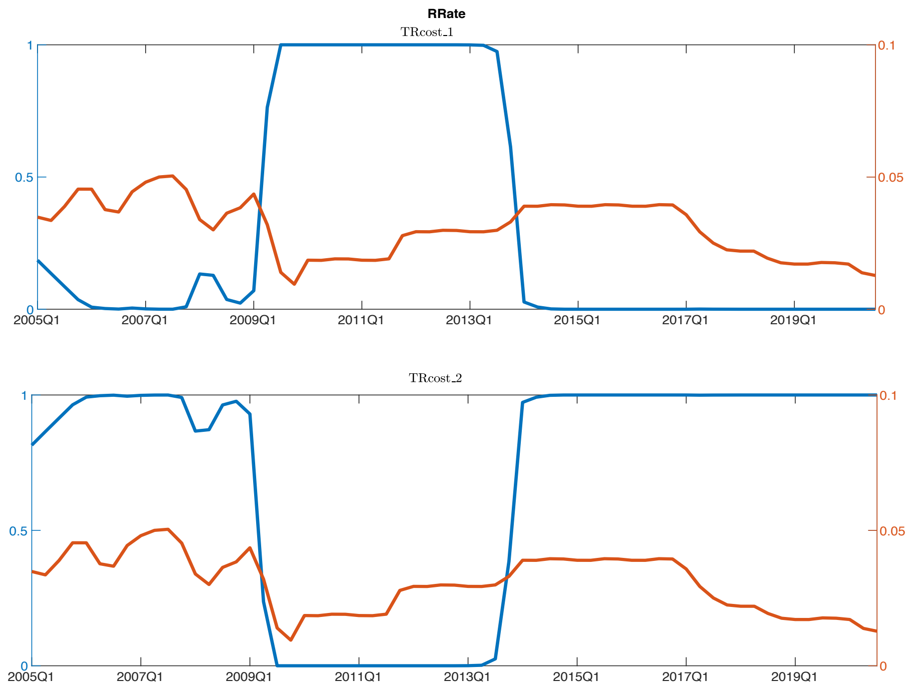

Figure 4.6: TANK2 Model Smoothed Regime Probabilities and Interest Rate

4.5.2 Impulse Response Functions

From the estimated models in their three versions, for the RANK model in Figure:4.7, TANK model in Figure:4.8, and TANK1 model in Figure:4.9, the findings confirm that monetary policy transmission mechanism has become relatively stronger.

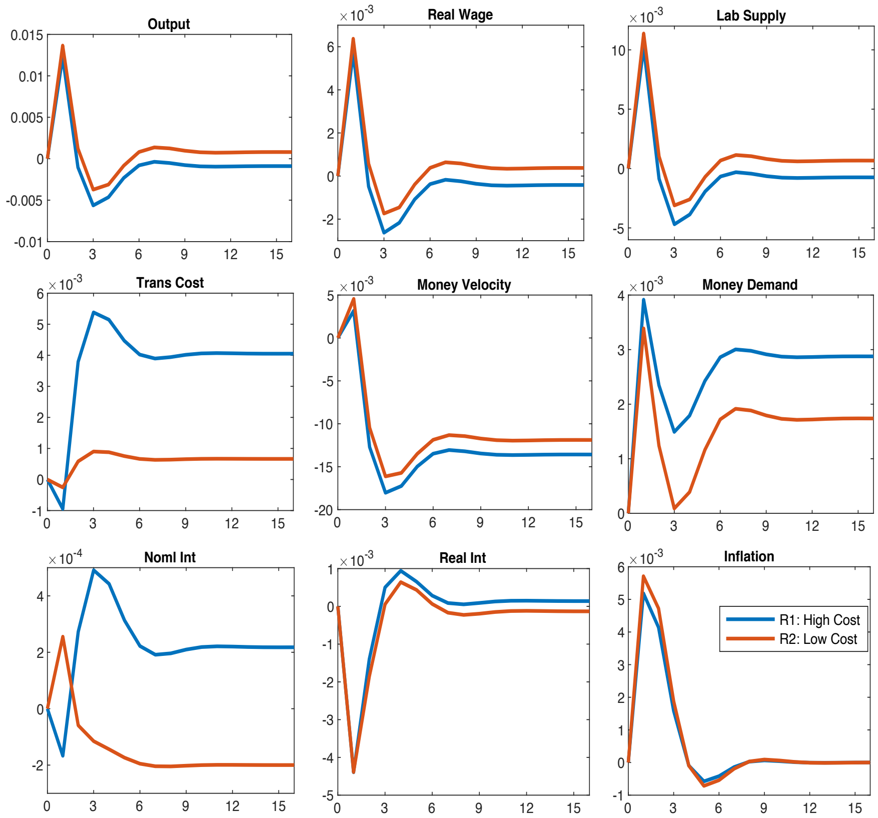

Figure 4.7: Impulse Response Function for RANK Model

The decrease in transaction cost increases money velocity that makes monetary policy transmission mechanism to be more effective. Because expected inflation rise leads to a much stronger reaction to the decrease in real interest rate ultimately stimulates aggregate demand. This showcases that monetary policy is more effective after introduction of mobile money.

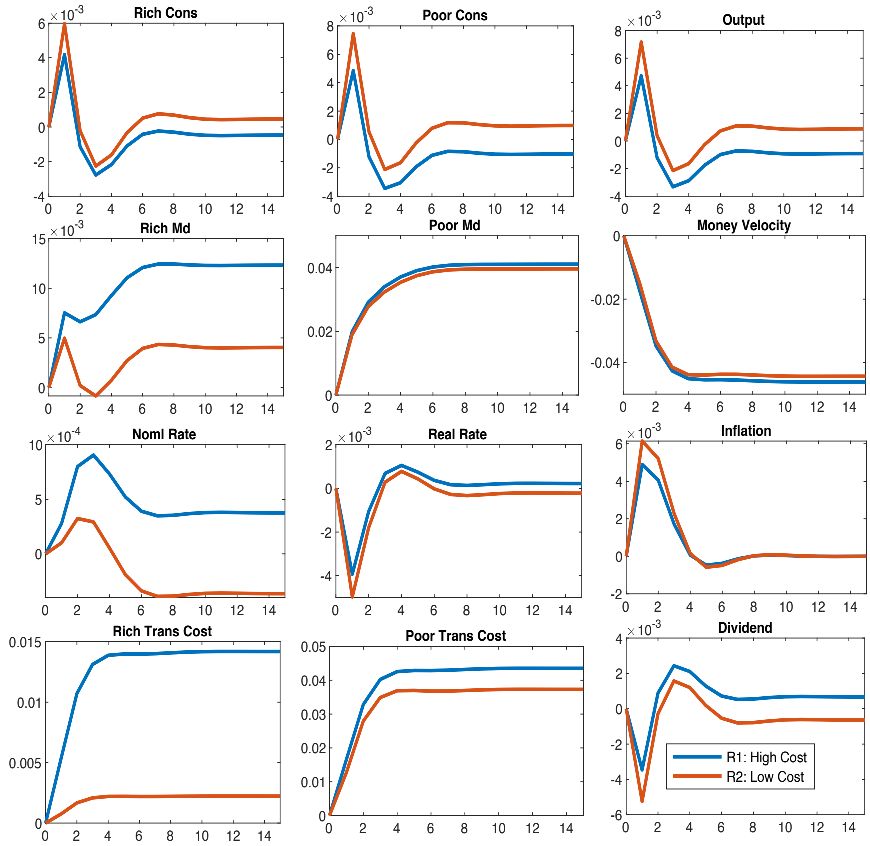

Figure 4.8: Impulse Response Function for TANK1 Model

A shock from money supply, using money growth rule, leads to the increase in output, consumption, expected inflation thus decline in real rate. When there is decrease in transaction cost resulting from FinTech products, there is substantially increase in consumption and output as compared when transaction cost ere high.

A common phenomenon that has been set out by the two versions of TANK models is a weakly identification of the decrease in transaction cost among the poor households and this can be interpreted in two ways.

First, FinTech has brought service in the economy that was not existing before, therefore poor households they used to rather "put their money under mattress", of which there was no cost involved while they executed transactions on cash basis. On the other hand Mobile money has brought convenience which is more used among the poor which can be viewed as cost to them, that is why there is small reduction in cost for them . The second reason the observed data is not sufficient enough to capture that effect as we used GDP which might be difficult to capture the heterogeneity among rich and poor Households.

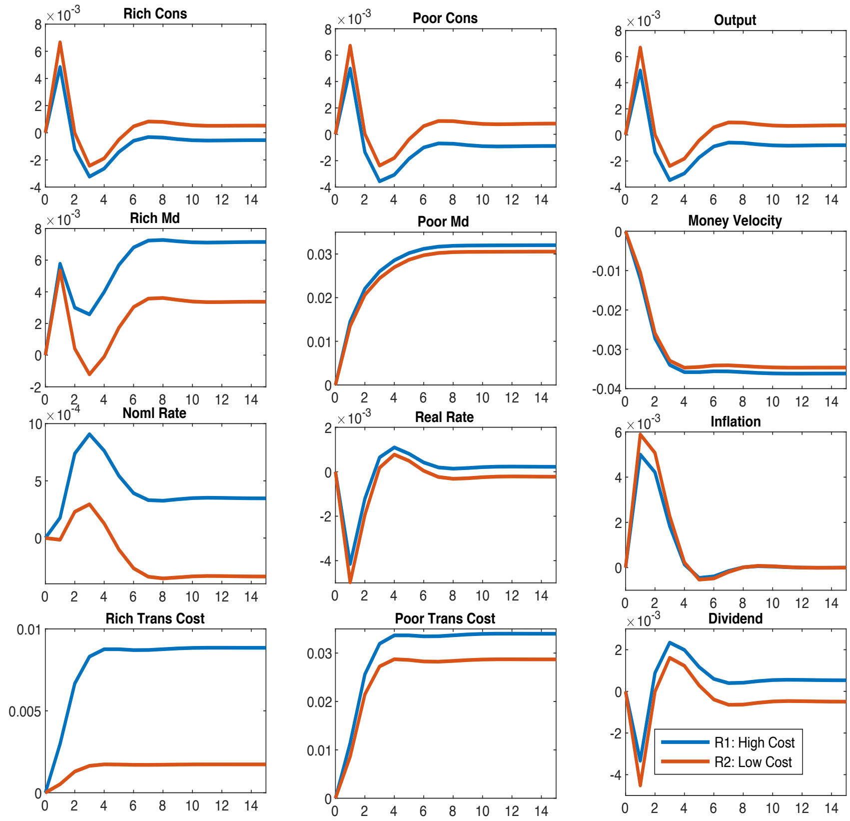

Figure 4.9: Impulse Response Function for TANK2 Model

The estimated regime switch from TANK models shows the timing is the same just like the RANK model, this provides a robust evidence of the changing in the policy transmission mechanism which is almost the same as the evidence from Markov switch VAR model in Chapter: 2, and from simulation of constant parameter model, as they both concluded that monetary policy has become relatively stronger after adopting FinTech. Also the estimated coefficient of CRRA in Tanzania is 0.5 that is consistent with the empirical study by Gandelman and Hernández-Murillo (2015) which results shows it ranges between 0.5 to 2.1

4.6 Policy Implication and Conclusion

Regime switching DSGE model has been able to provide a significant evidence that, Tanzania economy has at least experienced some structural changes which can be associated with the changes in Monetary Policy transmission mechanism.

The estimated three models under different assumptions of the Markov process that controls transaction cost have proved to be able to identify the regime switch which is consistent with results of VAR model, and simulations from the constant parameter model.

Mobile money has provided households with access to formal financial services, which previously were isolated by monetary policy actions. As more people use the new FinTech products result a decrease in transaction and portfolio adjustment costs thus a more effective monetary policy to stabilize the economy.

Technology provides liquidity, such as credit cards, reduces the demand for money, since these payment substitutes provide a means of payment without the need to hold money. Likewise, lower transfer costs and faster transfers between accounts will lower the demand for money

In order to fully embrace the challenges and opportunities brought by FinTech the country's monetary authority has to consider adopting using interest rate as an operating target. This is due to fact that, now a greater share of economic activity will be influenced by central bank interest rates because of a stronger inter-linkage between policy and real variables. This implies that changes in policy interest rate will have a greater more direct effect on larger number household's inter-temporal consumption and investment decisions thus will enhance the tools of stabilizing the economy if its derailed from its trajectory.

Appendix

Appendix 4.A Figures and Tables

Parameter	Description	Distribution	Prior		Posterior	
			Mean	Std dev	Mean	Std dev
	RANK Model					
$P_{Tc}^{h,l}$	Transition probability (High-Low)	Beta	0.2	0.1	0.1328	0.0179
$P_{Tc}^{l,h}$	Transition probability (Low-High)	Beta	0.2	0.1	0.1062	0.0164
$\gamma(S_t^{Tc} = High)$	Transaction cost	Beta	0.35	0.12	0.3112	0.0940
$\gamma(S_t^{Tc} = Low)$	Transaction cost	Beta	0.05	0.05	0.0559	0.0101
	TANK1 Model					
$P_{Tc}^{h,l}$	Transition probability (High-Low)	Beta	0.2	0.10	0.1102	0.0118
$P_{Tc}^{l,h}$	Transition probability (Low-High)	Beta	0.2	0.10	0.1073	0.0135
$\gamma_p(S_t^{Tc} = High)$	Rich hh. transaction cost	Beta	0.95	0.02	0.9405	0.0183
$\gamma_p(S_t^{Tc} = Low)$	Rich hh. transaction cost	Beta	0.55	0.15	0.8256	0.0365
$\gamma_r(S_t^{Tc} = High)$	Poor hh. transaction cost	Beta	0.35	0.2080	0.3166	0.0753
$\gamma_r(S_t^{Tc} = Low)$	Poor hh. transaction cost	Beta	0.05	0.0501	0.0493	0.0079
	TANK2 Model					
$P_{Ta}^{h,l}$	Transition probability (High-Low)	Beta	0.2	0.1	0.0986	0.0113
$P_{Ta}^{l,h}$	Transition probability (Low-High)	Beta	0.2	0.1	0.1042	0.0092
$\gamma_p(S_t^{Ta} = High)$	Rich hh. transaction cost	Beta	0.95	0.02	0.9503	0.0157
$\gamma_p(S_t^{Ta} = Low)$	Rich hh. transaction cost	Beta	0.55	0.15	0.8269	0.0249
$\gamma_r(S_t^{Ta} = High)$	Poor hh. transaction cost	Beta	0.35	0.12	0.2553	0.0367
$\gamma_r(S_t^{Ta} = Low)$	Poor hh. transaction cost	Beta	0.05	0.01	0.0455	0.0072
$\Psi(S_t^{Ta} = High)$	Poor hh. adjustment cost	Beta	0.25	0.12	0.1232	0.0363
$\Psi(S_t^{Ta} = Low)$	Poor hh. adjustment cost	Beta	0.0025	0.0015	0.0028	0.0012.

Table 4.A.1: Bayesian Estimation Results (Comparison)

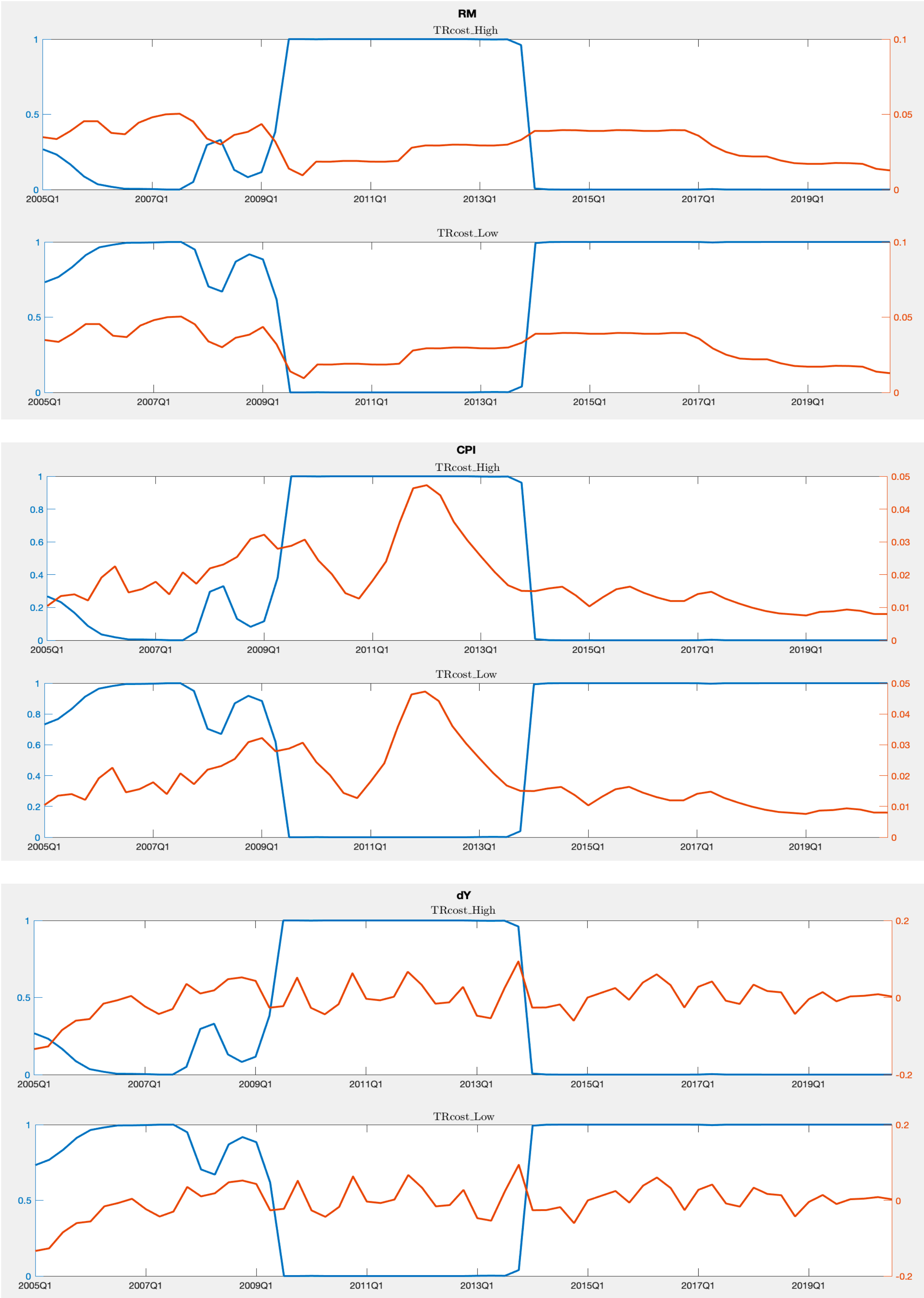

Figure 4.A.1: RANK: Smoothed Regimes against Data

Figure 4.A.2: TANK1: Smoothed Regimes against Data

Figure 4.A.3: TANK2: Smoothed Regimes against Data

Chapter 5

Concluding Remarks

Structural changes in the economy are real and are worth considering for monetary policy analysis. This has been demonstrated by this study by applying different tools of macroeconomic analysis which allows for the structural breaks to play part and results have shown are worth considering.

Technological advancements in financial sector through different Fintech products have proved to have positive effects for financial inclusion in emerging and advanced economies, like Tanzania and the convenience that FinTech provides to individuals with low and variable income is often more valuable to them than the higher cost they will pay to obtain such services from conventional regulated banks.

This implies that an increase in financial inclusion interacts with monetary policy by allowing more consumers to smooth their consumption over time, thus providing a potential platform to influence basic monetary policy choices. Moreover it encourages consumers to move their savings away from physical assets and cash into deposits which has been very common among large number of Tanzanians especially those who live in the rural areas . This may have implications for monetary policy operations and the role of intermediate policy targets as the result from this study highlighted.

All the models have shown a consistent verdict that regime after introduction of mobile money has at least improved effectiveness of monetary policy transmission mechanism. This alerts its paramount for the central bank to pay a closer attention to its challenges and opportunities to make informed policy decisions. Inflation and output respond reasonably better for MS-VAR model while in the simulation interest rate have indicated a stronger response when we allow for transaction cost hence velocity to change.

FinTech has provided households with access to formal financial markets and services thus increase in borrowing and savings which increases the amount of cash and assets in the banking system. Subsequently, monetary policy actions become more effective since changes operational target such as reserve money will have direct effects money supply,

The analysis suggests that financial inclusion can enhance central banks' ability to stabilize economic activity. More effective transmission of interest rate changes from greater financial inclusion reduces reliance on more direct and quantitative interventions by central banks when conducting countercyclical operations. Even though financial inclusion accentuates the distributional impact of monetary policy, central banks' increased ability to fine-tune policy with rising financial inclusion often accompanied by greater institutional emphasis on price stability means that overall economic volatility can be reduced, as observed in more advanced economies. Nevertheless, care should be taken when central banks tighten monetary policy, as its adverse impact on income distribution tends to be amplified as financial inclusion increases.

Financial Innovation has provided households with access to formal financial markets thus to services and instruments that facilitate borrowing and savings which increases the amount of cash and assets in the banking system. Subsequently, monetary policy actions becomes more effective since changes operational target such as reserve money will have direct effects money supply, therefore improving the effective implementation of monetary targeting. However this comes with challenge of volatility in velocity which hence instability in money demand function, which provides an opportunity for the monetary authority to keenly pay attention and put in appropriate measures.

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