INFORMAL CREDIT INTERMEDIATION AND MONETARY POLICY IN DSGE MODEL

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Abstract

This study expanded the hitherto DSGE model with bank intermediation to include informal credit intermediation. The modeling strategy assumed that both formal and informal banks operate in a common credit market performing the same activities, thus existing parallel to each other. Formal banks participate in the wholesale credit market whiles informal banks do not. The purpose of this modeling approach is to investigate the effect of the parallel activities of these banks on monetary transmission mechanism.

The study found that the presences of informal intermediation affect how interest rate react to monetary policy shocks. The effect however, depends on the relationship between formal and informal bank in the intermediation process. The study established that interest rates become very responsive to monetary policy if formal banks serves as lender of last resort to informal banks in the credit creation process. The contrast happens if informal banks are independent of formal banks in the credit creation process.

Keywords: Informal Credit, Bank Intermediation, DSGE
JEL Classification:

1 Introduction

Microfinance[1] involves the provision of financial services and management of small amounts of money through a range of products and a system of intermediary functions that are targeted at low income clients. The institution of modern micro-finance evolved to augment the development agenda of developing countries by serving as

[1] *For the purpose of this study microfinance which is used analogously and interchangeably with informal banks consists of financial intermediaries that do not participate in the interbank market and are not required by law to keep reserves with the central banks*

catalyst to minimize poverty and close the inequality gap. This, they achieve by providing financial and social intermediation services to low income earners and informal sector that constitute about 80 percent of developing economies. As it is noted, access to financial services is imperative for the development of the informal sector and helps to mop up excess liquidity through savings that can be made available as investment capital for national development (World Bank-Africa Region, 1999).

The structures and modus operandi of microfinance provide solace in the financial system of most economy by providing clients with products that are flexible and tailored to offer adequate financial services to the large percentage of people who do not fit into the commercial banking system. It also serves as a tool to mop up extra liquidity while offering other social intervention services to bring economic empowerment to the poor. Notwithstanding this core objective of their activities, microfinance activities have transformed into major financial activities whose activities do not only center on the poor but also includes activities that compromised the backbone of their establishment[2].

Over the years, microfinance activities have gain momentum and have grown to become very important component of modern financial system in both developed and developing economies. Its share in total financial intermediation has been increasing across countries. It is estimated that the volume of financial activities via the non-bank sector constitute about 40 percent in total world financial intermediation (FSB, 2014). Although data is sparse, anecdotal evidence suggests a similar trend in Ghana. For example, the amount of loans extended by Non-Bank Financial Institutions (NBFIs) increased from GH¢70.63 million in 2003 to GH¢72.85 million in 2004, suggesting 3.1 percent growth. In 2006, a total of GH¢160.47 million was extended to clients, which represents 48.8 percent higher than the previous year's total loans and advances granted by these micro-finance institutions. The upward- trending of NBFI's credit to individuals, small businesses, groups and others indicates marked improvements in the level of micro-finance and the gradual growth in total financial

[2] *In Ghana, microfinance institution has been the route by which investors without the capital requirement to establish universal banks use to accumulate more capital through deposit. After accumulating the required capital through microfinance activities, they transformed fully into universal bank operating as universal bank via the microfinance approach. Microfinance institutions such as union saving loans, capital plus, UT financial services among others have metamorphosed into omini bank, capital bank and UT bank respectively*

assets in the country. Overall, figures from Bank of Ghana (BoG) indicate that the share of micro-finance loans and advances as a percentage of total assets of banks and NBFI loans and advances has increased from 4.8 percent in 2008 to 9.8 percent in 2013.

There are number of issues associated with the growth of informal credit activities. First, there is evidence that the operations of informal banks and the traditional(universal) banks overlaps in most developing economies especially Ghana. Though, the theory underpinning the emergence of informal banks required them to operate in different markets, there is evidence [3] that these types of banks operate in similar market. This parallel operation has caused these banks to compete among themselves rather than complementing each other in the credit market. Secondly, informal credit activities do not fall strictly under the regulatory environment of central bank as the universal banks. Whiles the universal banks are required by law to keep some reserve with the central bank [4], informal banks are not mandatory to do so, even though, their operations are parallel to each other.

The ensuing question following the above problems is that could the interplay of these banks affect the effectiveness of monetary policy? This is because, banks play pivotal role in the conduct of monetary policy by serving as the channel through which monetary impulses are transmitted to the real sector. These are achieved through the banks relationship with the central bank via various regulatory framework such as the mandatory reserve requirements, discount windows and among others. Contrary to formal banks, informal banks do not associate with the central bank on this windows. This notwithstanding, the activities of informal banks parallel that of formal banks, with informal credit serving as alternative to formal credit in the credit market. By this, informal credit intermediations serves as leakages in the money multiplier process. The question therefore is could the parallel operations of informal banks coupled with its increasing share in credit intermediation affect monetary policy? That is, does the size of informal lending mar or improve transmitting monetary impulses? In view of these questions, the main objective of the study is to understand the role of informal credit intermediation in influencing the effectiveness

[3] *Even though, there is no empirical evidence to support this, trends in the Ghanaian system via anecdotal reports supports this*

[4] *The central bank conducted monetary policy through the universal banks by using the required reserve*

of monetary policy in DSGE framework.

2 Brief Literature

The literature identifies few papers that model informal (shadow) credit intermediation using DSGE approach. The notable ones include Verona et al, (2013), Meeks et al (2014), Mazelis (2014) and Funke et al, (2015). Though, these papers are closely related and complement each other in modeling the shadow banking sector, they differ in some dimension, particularly the role of shadow banks in the economy. Verona et al (2013) was concerned with the adverse selection effect of shadow banking on boom bust events caused by persistent low interest rate level. By this, they considered a financial accelerator DSGE model with formal banks investing in low risky projects whiles informal retail banks provide funding to riskier firms.

Mazelis (2014) explored the impact of monetary policy shocks on aggregate loan supply with both commercial and shadow banks. The paper extended Gertler and Karadi (2011) model with a non-bank financial intermediary to distinguish between bank and non-bank intermediaries based on the liquidity of their credit claims. In the model, banks could endogenously create deposits to fund their loans, however, non-banks had to raise deposits on the funding market to function as intermediaries. The funding market is modeled via search and matching by non-banks for available deposits of households. The paper showed that because deposit creation responds to economy-wide productivity automatically, bank reaction to shocks correspond to the balance sheet channel whiles non-banks are constrained by the available deposits making their behavior better explained by the lending channel. However, the two credit channels are affected differently following a monetary policy shock. By these counteracting effects, the study showed that an increasing non-bank sector leads to a reduced reaction of aggregate loan supply following a monetary policy shock, which is consistent with the data.

Meeks et al (2014) modeled the shadow sector similar to Mazelis (2014). However, unlike Mazelis (2014), Meeks et al, (2014) investigated how financial instability emanating from commercial banks was unloaded as risky loans to off-balance sheet shadow banks through securitization.

Funke et al (2015) modeled multifaceted interactions between non-standard monetary policy, the traditional banking sector and shadow banking sector in China to

analyze monetary policy transmission with parallel shadow banking and different degrees of interest rate controls. Comparing different interest rate liberalization scenarios, the study revealed that monetary policy shock increase feed-through to the lending rate and investment under complete liberalization. Also, tighter regulation of interest rates in the commercial banking sector in China led to an increase in loans provided by the shadow banking sector.

This current study differs from the above existing studies in different dimensions. The above studies modeled the financial market to include both formal and informal(shadow) banks operating separately in different markets. In their set-up, formal banks operate in the low risk enterprise markets whiles informal banks deals with the high risk market. Unlike these other studies, this current study modeled the informal banks analogous to formal banks. Both formal and informal banks compete in a common credit market. Thus, banks (formal and informal) exist parallel with one another performing the same activities. The only difference is that unlike formal banks who have extra fund from wholesale market, informal banks do not. The study thus explores how the parallel existence of informal banks with formal banks impacts on effective monetary policy (i.e. transmission process).

3 The Model

This section outlines the basic framework for the study. The modeling approach follows a standard dynamic stochastic general equilibrium (DSGE) model with banking intermediation. This study expands the banking sector to include a formal and an informal bank. Though there is no attempt to model the complex interplay between formal and informal banks, the modeling technique abstract from the structural relationship between formal and informal banks in Ghana to illustrate policy issues. The abstracted economy is modeled to consists of six agents. These agents include the household, entrepreneur, retailers, formal bank, informal bank and the central bank (government). In the set-up, the banks and household are assumed heterogeneous whiles firms are homogeneous [5].

[5] *The informal sector in developing countries particularly Ghana consists largely of household that engage in SME's activities. The informal bank emerged to cater for these informal activities because large firms dealt directly with the formal banks. Therefore, assuming heterogeneous household to capture the taste for a particular bank proves plausible.*

The model is summarize as follows: There is a continuum of household with s share as non-Ricardian and $1-s$ Ricardian household. Ricardian household consumes, works and accumulates wealth by engaging with the financial intermediaries. They supply deposit and take loans from these banks. Following Gerali et al (2009) model, within the Ricardian household there are the borrowers (impatient) and savers (patient) types. The patient household saves by purchasing deposit facilities from either the formal or informal bank. Impatient household also secure loan facilities (borrow) from the two financial institutions to finance their consumption. However, agent differ in their degree of impatience i.e. agents have different discount factors which they apply to the stream of future utility. The share of patient household is given by v. The non-Ricardian or Rule of Thumb household do not accumulate wealth, hence they do not engage with the financial sector. They only supply their labor and spend their labor income on final goods and services [6].

Both the formal and informal bank accept deposits (in the form of saving instrument) from households and advance loans as well. The banks face homogeneous or common credit market. Formal banks capture some proportion of the market which is exogenous determined. The available loan an agent can access is constrained by the future collateral holdings. Households borrowing are constrained by their future labor income[7]. This assumption by which banks collateralize debt with future labor income is different from studies such as Iacoviello (2005) and Gerali et al, (2009) that used housing stock as collateral to borrowing.

The banks operate in a monopolistic competition environment. Thus, they set interest rates on deposits and loans in order to maximize profits. The formal bank finances its' loan by the amount of deposits it accumulates from the household and wholesale market whiles the informal bank loan is financed from deposit accumu-

[6] *Applying DSGE modeling technique to developing economies usually suffers from the rational expectation criticism. This criticism is premised on the grounds that the proportion of the poor who can barely cater for their immediate need is high. As a result, they do not engage in inter-temporal rational expectation but rather naively extrapolate their current income into the future. Also, even if they do, they weigh their current income too heavily when looking ahead to their future income because current income is the only salient piece of information available to them. Their role in the model is captured by their proportion which affects the rational expectation dynamics.*

[7] *The study adopted this assumption because it is consistent with how financial institutions advance loans to households in Ghana. Even though, formal banks accepts fixed assets as collateral, we assume both banks accept future income as collateral for simplicity*

lated from the household and loans from the formal bank. Given that the formal bank secures additional income from the wholesale market but the informal banks do not, the capital structure of the formal bank is thus related to the central bank via the wholesale activities. On the other hand the Informal bank's capital is not related to wholesale lending activities. By this means, the central bank can control the credit supply of formal bank but not that of informal bank.

Workers are assumed to supply identical labor services. The labor services are supplied through a competitive labor packer that supplies unitary labor inputs to firms. As result there exist a unique wage obtained in a competitive setting. In addition, there is a monopolistic competitive retail sector which purchases intermediate goods in a competitive market from the entrepreneur. The retailer brands the intermediate goods at no cost and sell the differentiated goods at a price which includes a mark-up over purchasing cost and adjustment cost. To fix the modeling ideas and notation, the proceeding sections deals with each sector in turns.

3.1 Household

The household block consists of s rule of thumb and $1-s$ Ricardian. The Ricardian owns firms and financial assets in the economy. Within the Ricardian group are v fraction of patient household denoted as p and $1-v$ impatient household denoted as m. The difference in agents arise from the discount factor, which is higher for patient agents than impatient agents. The size of the discount factor indicates the level of impatient in agent which determines the magnitude of borrowing. Using β^h to represent the discount factor, the representative household group maximizes the expected utility given by

$$E_0 \sum_{t=0}^{\infty} \beta_t^s \left[\frac{{C_{it}^h}^{1-\theta}}{1-\theta} - \frac{{N_{it}^h}^{1+\phi}}{1+\phi} \right] \tag{3.1}$$

For $h \in \{p, m\}$ Where p and m represents patient and impatient household respectively. C_t and N_t denote consumption and labor supply respectively. θ is the risk averse parameter which indicates the risk behavior of the household.

3.1.1 Patient Household

The patient household finances expenditure on current consumption C_t^p and deposits D_t with stream of resources consisting of wage earnings $\left(W_t N_{it}^p\right)$, gross income of previous deposit $\left[\frac{1+R_{t-1}^d}{\pi_t}\right] D_{it-1}$ and a lump sum transfer (T^p). The lump sum transfers include both dividend from the retail firms and the banking sector. Formally, the budget constraint of the representative household in real term is thus specified as

$$C_{it}^p + D_{it} = W_t N_{it}^p + \frac{1+R_{t-1}^d}{\pi_t} D_{it-1} + T^p \tag{3.2}$$

π_t is the gross inflation defined as P_t/P_{t-1} and W_t is the wage rate. The total deposit D_t held by the household is the aggregation of deposit appropriated between formal and informal bank. R_t^d is the aggregate interest index paid on deposits. The household maximizes it's expected utility given by equation (3.1) subject to the budget constraint by optimally choosing deposit, labor supply and consumption. The resulting first order conditions from the maximization problem are given by

$$\lambda_t^p C_t^{p\theta} = 1 \tag{3.3}$$

$$W_t = C_t^{p\theta} N_t^{P\phi} \tag{3.4}$$

$$\lambda_t^p = \beta_p E_t \left(\lambda_{t+1}^p \frac{1+R_t^d}{\pi_{t+1}} \right) \tag{3.5}$$

Where λ_t^p as the budget constraint multiplier

3.1.2 Impatient Household

The impatient household neither hold deposits nor own retail firms but only receive income from their labor service. They only incur expenditure on their current consumption and reimbursement of past borrowings. These expenses are financed with income from labor services and new borrowing. The budget constraint facing the household is

$$C_{it}^m + \frac{1+R_{t-1}^{bm}}{\pi_t} B_{it-1}^m = W_t N_{it}^m + B_{it}^m + T^m \tag{3.6}$$

B_t^m is the aggregate loan secured from both formal and informal banks. R_t^{bm} is the aggregate interest index charged on the loan. The amount of new borrowing the household can secure from the bank is constrained by the expected value of its collateral. The household uses the future value of her labor income as collateral [8] to secure loan from the financial sector. To satisfy the non-Ponzi assumption, the expected value of the collateral services should be sufficient to guarantee debt repayment. This constraint is specified as

$$(1+R_t^{bm})B_{it}^m = \mu_t^m E_t\left[W_{t+1}N_{it}^m \pi_{t+1}\right] \tag{3.7}$$

where μ_t^m is the loan-to-value ratio (LTV) for labor income.

The household maximizes equation 3.1 subject to both the expenditure and borrowing constraints. Using λ_t^m and V_t^m as the budget constraint multiplier and borrowing constraint multiplier respectively, the FOCs are then given as

$$\lambda_t^m C_t^{m\theta} = 1 \tag{3.8}$$

$$N_t^{m\phi} = \lambda_t^m W_t + V_t^m \mu_t^m E_t[W_{t+1}\pi_{t+1}] \tag{3.9}$$

$$(1+R_t^{bm})V_t^m + \beta_m E_t\left[\lambda_{t+1}^m\left(\frac{1+R_t^{bm}}{\pi_{t+1}}\right)\right] = \lambda_t^m \tag{3.10}$$

3.1.3 Non-Ricardian

The non-Ricardian or rule of thumb household do not have access to financial markets. They are only concerned about their labor income. This gives rise to their budget constraint as

$$c_t^r = W_t N_t^r \tag{3.11}$$

[8] *Unlike Gerali et al, (2009) that used housing as collateral for the household, this study used labor income. This assumption is consistent with bank lending practices to household in developing countries especially Ghana, where household borrow against their labor income. Although, formal banks accept fixed assets and other forms of collateral, this study assumed both banks uses labor income as collateral for simplicity.*

3.1.4 Loans Demand and Deposit Supply

Loan Demand: Household borrow from formal and informal banks designated as f and I respectively. The aggregate loans are given by a composite CES basket of slightly differentiated products which are each supplied by a formal bank j and informal bank j.

To capture the market power that characterize the banking industry, the study follows Benes and Lees (2007) and Arce and Andres (2008) to treat the credit market analogously as the standard Dixit-Stieglitz framework for the goods market. In this set-up, each agent demands loan contract from each single financial institution in order to borrow one unit of resources. The aggregate loan demanded by a household i is expressed as

$$B_t^m = \left(g^{\frac{1}{\epsilon^m}} b_t^{mf\,\frac{\epsilon^m-1}{\epsilon^m}} + (1-g)^{\frac{1}{\epsilon^m}} b_t^{mI\,\frac{\epsilon^m-1}{\epsilon^m}} \right)^{\frac{\epsilon^m}{\epsilon^m-1}} \tag{3.12}$$

g is the share of formal bank loan in household credit basket. b represents loans obtained from the banks. ϵ^m is the elasticity of substitution between the formal and informal credits [9].

Denoting r_t^{bmf} and r_t^{bmI} as the interest rate facing household from formal and informal bank respectively, the total due payment to household for borrowing from each sector is specified as

$$\int_0^1 r_t^{bmf}(j) B_t^{mf}(j)\,dj + \int_0^1 r_t^{bmI}(j) B_t^{mI}(j)\,dj \tag{3.13}$$

The demand schedule is thus derived by minimizing the total interest payment subject to the aggregate loan demand in equation 3.12 Aggregating f.o.c's across impatient agent result in the demand for credit from various sectors as

$$B_t^{mf} = g \left[\frac{r_t^{bmf}}{R_t^{bm}} \right]^{-\epsilon^m} B_t^m \tag{3.14}$$

$$B_t^{mI} = (1-g) \left[\frac{r_t^{bmI}}{R_t^{bm}} \right]^{-\epsilon^m} B_t^m \tag{3.15}$$

[9] *The elasticity measures competition between formal and informal credit in the household credit basket*

The average interest rate on loans to household is given by the composite aggregation

$$R_t^{bm} = \left[g r_t^{bmf\,1-\epsilon^m} + (1-g) r_t^{bmI\,1-\epsilon^m} \right]^{\frac{1}{1-\epsilon^m}} \tag{3.16}$$

Deposit Supply:The patient household supplies deposit to both the formal and informal sector. The household aggregate basket of deposit is a composite of both the formal and informal deposit which is expressed as

$$D_t = \left(k^{\frac{1}{\epsilon^d}} D_t^{f\,\frac{\epsilon^d-1}{\epsilon^d}} + (1-k)^{\frac{1}{\epsilon^d}} D_t^{I\,\frac{\epsilon^d-1}{\epsilon^d}} \right)^{\frac{\epsilon^d}{\epsilon^d-1}} \tag{3.17}$$

k is the share of formal sector deposit in the household deposit basket. D_t^f and D_t^I are the deposits held with formal and informal bank respectively. ϵ^d is the elasticity of substitution between the formal and informal deposit. The household maximizes the total return specified in equation 3.18 from saving with the banks. Where r_t^{df} and r_t^{dI} respectively denote formal and informal deposit rate

$$\int_0^1 r_t^{df}(j) D_t^f(j)\,dj + \int_0^1 r_t^{dI}(j) D_t^I(j)\,dj \tag{3.18}$$

Subject to equation 3.17 Aggregating across household results in the deposit supplied to each bank as

$$D_t^f = k D_t \left[\frac{r_t^{df}}{R_t^d} \right]^{-\epsilon^d} \tag{3.19}$$

$$D_t^I = (1-k) D_t \left[\frac{r_t^{dI}}{R_t^d} \right]^{-\epsilon^d} \tag{3.20}$$

The average lending rate is also given as

$$R_t^d = \left[k r_t^{df\,1-\epsilon^d} + (1-k) r_t^{dI\,1-\epsilon^d} \right]^{\frac{1}{1-\epsilon^d}} \tag{3.21}$$

3.2 Financial Intermediation Sector

The financial sector is the key sector of this model. There are two types of financial intermediaries - formal and informal bank. In the model set-up, we assume there

is a common credit market which faces the financial institutions. In reality these banks operate in segmented markets. Whiles formal banks service the formal sector of the economy i.e. low risk agents, informal banks in contrast emerged to cater for the informal economy which are perceived the high risk agents. However, we make assumption of common market for two reasons:

- Firstly, there is a common trend in Ghana where the activities of these banks overlap[10]. With the exception of medium and large scale firms that mostly bank with formal banks, both banks compete over the household market. Since, we modeled the banks to only deal with household it suffice to make the assumption of common market to depict this situation in Ghana.

- Secondly, the main aim of this study is to investigate how competition between formal and informal banks in the intermediation process affect monetary transmission. Therefore, modeling banks to operate in common market will bring forth this competition with simplicity. Therefore, the common market assumption is made for modeling simplification.

The only saving instrument offered by banks to patient households is bank deposits. Also, the only way impatient households can borrow from the banks is by applying for a bank loan. A feature of the banks is the ability of them to set rates on their instruments. The banks compete among themselves within each sector and also between Sectors to collect deposits and supply loans.

We also assume that banks obey a balance sheet identity where banks can finance their loans B_t using either deposit D_t or bank capital (equity) K_t^b as in

$$B_t = D_t + K_t^b$$

In view of the balance sheet identity, the two sources of finance are substitutes. However, banks are assumed to have exogenous optimal leverage (capital-to-asset) ratio. This introduces imperfect substitution in the balance sheet constraint. The optimal constraint is perceived as banks decision regarding how much of it's own resources

[10] *The 2014 edition of Ghana banking survey conducted by Price Water Coopers(PWC) identified non traditional credit sources as the major challenge facing the traditional sources, thus causing threats to their operations. Though, there is no empirical evidence on credit overlap, the identify threat show some evidence that the two types of banks operate in a similar market*

to hold. By this assumption, bank capital will have a key role in determining the conditions of credit supply, both for quantities and for prices.

The formal bank participates in the credit wholesale market hence has access to additional funds from this market. On the contrary, the informal bank does not have access to the wholesale market, rather, informal bank can obtain extra fund from the formal sector and also deposit excess funds with them. By this assumption, the central bank can control the supply of credit of the formal bank by influencing the reserve structure of formal banks but not that of the informal bank. The goal of the banks is to maximize profit from the intermediation process.

3.2.1 Formal Bank

This bank consists of a wholesale branch and retail branch. The wholesale branch manages the wholesale credit activities of the bank. The retail branch is responsible for raising differentiated deposits from the household and giving out differentiated loans.

Wholesale Branch: The wholesale branch combines net worth (capital and deposit) to issue loans on the wholesale market. The bank invests in liquid asset. The asset can always be exchanged against central bank liquidity if it desires to increase liquidity on the wholesale market. Given the identical funding structure across wholesale banks, the interest paid on deposit will be the same across banks[11]. The interest rate prevailing in the wholesale market is thus determined by the profit maximizing behavior of the banks. However, given the banks similarity, banks considering lending in the wholesale market takes the policy rate set by the central bank as given and decides optimally about the amount of liquidity to supply.

The wholesale activity is assumed to generate a cost related to the capital position of the bank. That is the bank pays a quadratic cost whenever the capital to asset ratio $\left(\frac{K_t^b}{B_t^f}\right)$ is in disequilibrium with the optimal value (V^b). The bank also retains part of the profit that accrued to the bank. Denoting the ratio of bank profit retained as ω^b, δ^b as the resources used in managing bank capital and conducting overall intermediation process and J^b as the profit of the bank, then the capital of the bank accumulate

[11] *It is assumed that the difference between the interest rate paid on deposits and the interest obtained from the investment in the liquid asset is negligible as a result, the optimization problem of the bank can be ignored.*

according to;

$$K^b_{jt} = (1-\delta^b)K^{b,n}_{jt-1} + \omega^b J^{b,n}_{jt-1} \tag{3.22}$$

The problem of this branch is thus to choose loans (B^f_t) and deposit (D^f_t) so as to maximize profit subject to a balance sheet constraint. Specifically,

$$MaxE_0 \sum_0^\infty \lambda^p_{0,t} \left[\left(1+R^b_t\right) B_{jt} - \left(1+R^d_t\right) D_{jt} - K^b_{jt} - \frac{K_{kb}}{2}\left(\frac{K^b_{jt}}{B_t(j)} - V^b\right)^2 K^b_{jt} \right] \tag{3.23}$$

s.t.

$$B^f_{jt} = D^f_{jt} + K^b_{jt} \tag{3.24}$$

The first order condition derived by linking the spread between wholesale rates on loans and deposit with the leverage ratio is given as

$$R^b_t = R^d_t - k_{kb}\left(\frac{K^b_{jt}}{B^f_{jt}} - V^b\right)\left(\frac{K^b_{jt}}{B^f_{jt}}\right)^2 \tag{3.25}$$

The model is closed by assuming that banks invest any excess fund in a deposit facility at the central bank remunerated a rate r_t such that $R^d_t = R_t$. [12] Assuming the wholesale market operate under a perfect competitive sittings, then the wholesale loan rate prevailing on market can be specified as

$$R^b_t = r_t - k_{kb}\left(\frac{K^b_{jt}}{B^f_{jt}} - V^b\right)\left(\frac{K^b_{jt}}{B^f_{jt}}\right)^2 \tag{3.26}$$

Equation 3.26 postulates the role of capital in determining loan supply. The relation indicates that as far as there exist wedge between loan and the policy rate the bank would increase loan supply, which will consequently increase leverage and profit per unit capital (i.e. return on equity). At the same time, increasing leverage reduces profit since the capital-to-asset ratio moves away from the cost (V^b). This trade-off causes the bank to choose loan level such that the marginal cost for reducing the capital-to-asset ratio is exactly equal to the loan-deposit spread.

Retail Branch: This bank takes wholesale loans at the rate R^b_t, differentiate them at zero cost and resell them to impatient household. The liability of the bank therefore comprises deposits and wholesale loans. The balance sheet of a formal bank is given by Table 1

[12] *This can also be viewed as banks purchasing government bond*

Table 1: Balance Sheet of a Formal Bank

Assets	Liability
Loans	Deposit
	wholesale Loans

The bank also gives loan facility to the informal when the later needs extra. The bank advances the loan to the informal bank at the same rate as the rate advanced to household. The bank maximizes over both interest r_t^{df} and r_t^{bf}. The bank faces quadratic adjustment cost for changing rates they charge on loans. The rational is to introduce stickiness to capture imperfect pass-through. Parametrizing the cost the branch incur from extending loans to and collecting deposits from household as K_{bf} and K_{df} respectively, then the profit of the bank can be specified as:

$$E_0\sum_0^\infty Q_t^p\Bigg\{r_t^{bf}(j)B_t^f(j)+r_t^{bf}(j)B_t^i-r_t^{df}(j)D_t^f(j)-r_t^{df}D_t^i-R_t^bIB_t(j)-$$
$$\frac{k_{bf}}{2}\left(\frac{r_{jt}^{bf}}{r_{jt-1}^{bf}}-1\right)^2 r_t^{bf}B_t^f-\frac{k_{df}}{2}\left(\frac{r_{jt}^{df}}{r_{jt-1}^{df}}-1\right)^2 r_t^{df}D_t^{ef}\Bigg\} \tag{3.27}$$

As deposits and loans are imperfect substitute both for banks within and between sectors, the maximization problem is subject to the following demand and supply function for household loan and deposits.

$$B_{jt}^f=g\left(\frac{r_{jt}^{bf}}{R_t^{bm}}\right)^{-\epsilon_t^m}B_t^m \tag{3.28}$$

$$D_t^f(j)=k\left(\frac{r_{jt}^{df}}{R_t^d}\right)^{-\epsilon_t^d}D_t \tag{3.29}$$

with $IB_t=B_t^f$

The first order conditions yields the interest rate function for loans and deposit respectively as

$$1-\epsilon_t^m+\left(\frac{R_t^b}{r_t^{bf}}\right)\epsilon_t^m+\frac{B_t^I}{B_t^f}-k_{bf}\left(\frac{r_t^{bf}}{r_{t-1}^{bf}}-1\right)\frac{r_t^{bf}}{r_{t-1}^{bf}}+Q_pE_t\left[\left(\frac{\lambda_{t+1}^p}{\lambda_t^p}\right)k_{bf}\left(\frac{r_{t+1}^{bf}}{r_t^{bf}}\right)^2\left(\frac{r_{t+1}^{bf}}{r_t^{bf}}-1\right)\left(\frac{B_{t+1}^f}{B_t^f}\right)\right]=0$$

$$-1+\epsilon_t^d-\epsilon_t^d\left(\frac{R_t^d}{r_t^{df}}\right)-\frac{D_t^I}{D_t^f}-k_{df}\left(\frac{r_t^{df}}{r_{t-1}^{df}}-1\right)\frac{r_t^{df}}{r_{t-1}^{df}}+Q_pE_t\left[\left(\frac{\lambda_{t+1}^p}{\lambda_t^p}\right)k_{df}\left(\frac{r_{t+1}^{df}}{r_t^{df}}\right)^2\left(\frac{r_{t+1}^{df}}{r_t^{df}}-1\right)\left(\frac{D_{t+1}^f}{D_t^f}\right)\right]=0$$

The simplified version of the loan and deposit setting rates are given by the log-linearized version of the above equation by assuming ϵ_t^s is non-stochastic. This is specified as

$$\widehat{r_t}^{bf}=\frac{k_{bf}}{R^*\epsilon_t^m+(1+Q_p)k_{bf}}\widehat{r_{t-1}}^{bf}+\frac{Q_pK_{bf}}{R^*\epsilon_t^m+(1+Q_p)k_{bf}}E_t\widehat{r_{t+1}}^{bf}+$$
$$\frac{\epsilon_t^mR^*}{\epsilon_t^m+(1+Q_p)k_{bf}}\widehat{R_t}^b+\frac{B^*}{R^*\epsilon_t^m+(1+Q_p)k_{bf}}(\widehat{B_t}^I-\widehat{B_t}^f) \tag{3.30}$$

$$\widehat{r_t}^{df}=\frac{k_{df}}{R_d^*\epsilon_t^d+(1+Q_p)k_{df}}\widehat{r_{t-1}}^{df}+\frac{Q_pK_{df}}{R_d^*\epsilon_t^d+(1+Q_p)k_{bf}}E_t\widehat{r_{t+1}}^{df}+$$
$$\frac{R_d^*\epsilon_t^d}{R_d^*\epsilon_t^d+(1+Q_p)k_{df}}\widehat{r_t}+\frac{D^*}{R_d^*\epsilon_t^d+(1+Q_p)k_{df}}(\widehat{D_t}^I-\widehat{D_t}^f) \tag{3.31}$$

Where

$$R^*=\frac{Rss^b}{rss^{bf}}$$
$$B^*=\frac{Bss^I}{Bss^f}$$
$$R_d^*=\frac{rss}{rss^{df}}$$
$$D^*=\frac{Dss^I}{Dss^f}$$

The simplified loan-setting equation shows that loan rates set by the formal banks takes into account the expected future path of the wholesale rate. The wholesale rate from equation (3.26) depends on the policy rate and the capital position of the bank. Also, equation 3.31 shows that banks set the deposit interest rate to take into account the expected future level of policy rate. The speed of adjustment to changes in the policy rate depends on the degree of substitution between informal and formal deposits and the adjustment cost.

Interest pass-through is given by

$$\frac{\partial\widehat{r_t}^{bf}}{\partial\widehat{r_t}}=\frac{R^*\epsilon_t^m}{R^*\epsilon_t^m+(1+Q_p)k_{bf}} \tag{3.32}$$

From equation (3.32), the pass-through depends on the elasticity of substitution between formal and informal loans as well as the cost of changing interest rates. If formal and informal loans are perfect substitute i.e. $\epsilon_t^m = 1$, then

$$\frac{\partial \widehat{r}_t^{\,bf}}{\partial \widehat{r}_t} = \frac{R^*}{R^* + (1+Q_p)k_{bf}}$$

This makes pass-through a function of only cost of adjusting prices and discount factor. In situations where informal bank does not interact with the formal bank in terms of accessing extra from them, the pass-through coefficient becomes

$$\frac{\partial \widehat{r}_t^{\,bf}}{\partial \widehat{r}_t} = \frac{\epsilon_t^m - 1}{\epsilon_t^m - 1 + (1+Q_p)k_{bf}} \tag{3.33}$$

Perfect substitution reduces the pass-through estimate to

$$\frac{\partial \widehat{r}_t^{\,bf}}{\partial \widehat{r}_t} = 0$$

This shows that monetary policy is ineffective in influencing retail rates if formal and informal credits are perfect substitute in the agents basket of credit demand. This postulates that monetary effectiveness depends magnificently on the elasticity of substitution between formal and informal credit. The more elastic the substitutability the more effective is the monetary policy. From the above analysis, it can be inferred that as credit market becomes segmented the influence of informal credit intermediation becomes negligible.

3.2.2 Informal Bank

The informal sector operates parallel to the formal sector in the credit intermediation process. The distinct feature is that unlike the formal bank, the informal bank do not engage in wholesale credit intermediation, hence they do not have wholesale unit. However, this bank deposits its' excess fund with the formal bank and obtain excess funds from them as well when they run out of liquidity at the prevailing rate of the formal bank. By this, their interest rate setting condition is not directly affected by central bank action (i.e. Policy rate), rather via the intermediate route of formal banks. The bank collect deposits (D_t^I) from patient household and pays them interest rate r_t^{dI}. Also, the bank extend loans B_t^I to households at rate r_t^{bI}. Like the

formal bank, the informal bank incurs quadratic adjustment cost to collect deposit and make loans as well. The bank solves the following problem

$$MaxE_0\sum_0^\infty Q_t^p\left\{r_{jt}^{bi}B_{jt}^i+r_t^{df}D_t^i-r_t^{bf}B_t^i-r_{jt}^{di}D_t^i-\frac{k_{bi}}{2}\left(\frac{r_{jt}^{bi}}{r_{t-1}^{bi}}-1\right)^2 r_t^{bi}B_t^i\right.$$

$$\left.-\frac{k_{di}}{2}\left(\frac{r_{jt}^{di}}{r_{t-1}^{di}}-1\right)^2 r_t^{dI}D_t^i\right\} \tag{3.34}$$

subject to

$$D_{jt}^I=(1-k)\left(\frac{r_{jt}^{dI}}{R_t^d}\right)^{-\epsilon_t^d}D_t \tag{3.35}$$

$$B_{jt}^i(j)=(1-g)\left(\frac{r_{jt}^{bi}}{R_t^{bm}}\right)^{-\epsilon_t^m}B_t^m \tag{3.36}$$

The first order conditions imposing symmetric condition of $r_t^{dI}(j)=r_t^{dI}$ at equilibrium result in the pricing relation for deposit and loans respectively specified as

$$-1+\epsilon_t^d-\left(\frac{r_t^{df}}{r_t^{dI}}\right)\epsilon_t^d-k_{dI}\left(\frac{r_t^{dI}}{r_{t-1}^{dI}}-1\right)\frac{r_t^{dI}}{r_{t-1}^{dI}}+Q_p\left[\left(\frac{\lambda_{t+1}^p}{\lambda_t^p}\right)k_{dI}\left(\frac{r_{t+1}^{dI}}{r_t^{dI}}\right)^2\left(\frac{r_{t+1}^{dI}}{r_t^{dI}}-1\right)\left(\frac{D_{t+1}^I}{D_t^I}\right)\right]=0$$

$$1-\epsilon_t^m+\left(\frac{r_t^{bf}}{r_t^{bI}}\right)\epsilon_t^m-k_{bI}\left(\frac{r_t^{bI}}{r_{t-1}^{bI}}-1\right)\frac{r_t^{bI}}{r_{t-1}^{bI}}+Q_p\left[\left(\frac{\lambda_{t+1}^p}{\lambda_t^p}\right)k_{bmI}\left(\frac{r_{t+1}^{bI}}{r_t^{bI}}\right)^2\left(\frac{r_{t+1}^{bI}}{r_t^{bI}}-1\right)\left(\frac{B_{t+1}^I}{B_t^I}\right)\right]=0$$

The log-linearized version of the loan rate for the informal sector when ϵ^s is assumed to be non-stochastic is given

$$\widehat{r}_t^{\,bI}=\frac{k_{bI}}{\epsilon^m-(1+Q_p)k_{bI}}\widehat{r_{t-1}}^{\,bI}+\frac{Q_pK_{bf}}{\epsilon^m-(1+Q_p)k_{bI}}E_t\widehat{r_{t+1}}^{\,bI}+\frac{\epsilon^m-1}{\epsilon^m-(1+Q_p)k_{bf}}\widehat{r}_t^{\,bf} \tag{3.37}$$

$$\widehat{r}_t^{\,dI}=\frac{k_{dI}}{\epsilon^d-(1+Q_p)k_{dI}}\widehat{r_{t-1}}^{\,dI}+\frac{Q_pK_{df}}{\epsilon^d-(1+Q_p)k_{dI}}E_t\widehat{r_{t+1}}^{\,dI}+\frac{\epsilon^d-1}{\epsilon^d-(1+Q_p)k_{bf}}\widehat{r}_t^{\,df} \tag{3.38}$$

From the equation, the loan rate in this sector does not depend on the wholesale rate. Rather, it depends on rates set by formal banks. These unique characteristics make the informal sector price-setting directly dependent on formal activities but indirect dependent on monetary authorities.

3.3 Entrepreneur

The entrepreneur produces intermediate good by combining effective labor in perfect competitive environment. The firm uses a Cobb-Douglas production technology function given as

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{3.39}$$

Where Y_t, and N_t denote intermediate good and aggregate labor from household respectively. A_t represent the level of technology which evolves exogenous according to an AR(1) stochastic process. The firm maximizes each period profit

$$P_t^w Y_t - W_t N_t$$

subject to its technology specified in equation 3.39 taking P^w wage as given. The first order condition yields

$$\frac{W_t}{P^w} = (1-\alpha) A_t N_t^{-\alpha} \tag{3.40}$$

3.4 Retailer

Retailers are only branders who purchase intermediate goods from entrepreneurs at wholesale price P_t^w. They operate in a monopolistic competitive environment and differentiate the goods at zero cost. Retailers set price at a mark-up over wholesale price and index prices to past prices at degree. Retailers index prices to a combination of past and steady state inflation, with relative weights parametrized by l. They also face quadratic price adjustment cost k_p when changing prices. The rational is to introduce price stickiness in the model. Retailers thus solve the problem

$$E_t \sum_{t=0}^{\infty} \lambda_t^P \left[p_t(j) y_t(j) - P_t^W y_t(j) - \frac{k_p}{2} \left(\frac{p_t(j)}{p_{t-1}(j)} - \pi_{t-1}^l \pi^{1-l} \right)^2 p_t y_t \right] \tag{3.41}$$

subject to a consumption aggregate

$$y_t(j) = \left(\frac{p_t(j)}{p_t} \right)^{-\epsilon_t^y} y_t \tag{3.42}$$

Imposing symmetric equilibrium, the FOC result in a non-linearized Philip curve for price inflation is specified as

$$1 - \epsilon_t^y + \epsilon_t^y \frac{P^w}{P} - k_p(\pi_t - \pi_{t-1}^l \pi^{1-l})\pi_t + \beta_p E_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} k_p(\pi_{t+1} - \pi_t^l \pi^{1-l})\pi_{t+1} \frac{y_{t+1}}{y_t} \right] = 0 \tag{3.43}$$

3.5 Monetary Policy

The central bank conducts monetary policy through a Taylor-rule function. It sets the short-term nominal interest rate (policy rate), R_t, in response to deviation of output y_t and inflation π_t from their respective target level. The interest rate reaction function is given as:

$$R_t = \epsilon_t^R r \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y}$$

where ϕ_{pi} and ϕ_y are the weights assigned to inflation and output stabilization respectively. r is the steady state nominal interest rate and ϵ_t^R is an exogenous shock to monetary policy.

3.6 Aggregation

Given that s share of household are non-optimizers and z share of optimizing households as savers, then aggregate labour and consumption are given respectively as

$$N_t = sN_t^r + z(1-s)L_t^p + (1-s)(1-z)L_t^m \tag{3.44}$$

$$C_t = sC_t^r + z(1-s)C_t^p + (1-s)(1-z)C_t^m \tag{3.45}$$

4 Model Analysis

This section analyzes the model behavior by investigating the model's reaction to perturbations in the economy. First, the study pins down the model parametrization. Then, investigates how monetary policy shock propagates through the economy, both with and without informal banks. Further, the study investigate the effect of monetary policy on aggregate loan supply depending on the relative share of intermediation via the informal banking system in the economy.

4.1 Steady State and Log-Linear

Following from the necessary conditions obtained in the previous section and presented in the appendix, the steady state of the model were estimated and the log linear version for studying the dynamics of the study were also presented. The steady

states are obtained by dropping the time index associated with the necessary conditions. The reduced steady states equations are presented in section **??** in the appendix. From the steady state equations, the ratio of formal interest rate to informal rate for both loans and deposits is a mark-up that are given respectively as the elasticity of substitution for the two types of loans and deposits. Using an appropriate initial values, we estimate the steady states value using nonlinear equation solver. We solve the steady state using Newton method with quadratic searching. Using a tolerance level of 1e-1 for 1-norm of residuals, the search was done using 500 iterations.

The log-linear version of the necessary conditions are given by a first order Taylor approximation around the steady states. The full lists of equations are presented in section in the appendix.

4.2 Calibration

The model is calibrated for the Ghanaian economy using monthly frequency as the time unit. Since the innovative part of the model is with the introduction of the informal banks and its relation with the formal banks, the model calibration focused on this part. These parameters were calibrated to replicate the statistical properties of Ghanaian data and to ensure steady state. The rest of the parameters were also calibrated using Ghana's data. However, those that were not easily calibrated or not available for Ghana were sourced from the literature.

The share of household that are non-optimizing (rule of thumb) is set at 0.25 . This is set in line with extreme poverty ratio [13]. The proportion of patient (savers) household is set at 0.1849 in accordance to 2014 national saving rate[14].

In line with the average monthly rate on fixed deposit rate among commercial banks for the year 2014, the steady state of formal deposit rate r^{df} is set at 15 percent. The average base rate for commercial banks is used for the formal sector lending rate. Using average between 2005 and 2014, the steady state formal lending rate r^{bf} is set at 28 percent. In the same way, using the average monthly deposit rate among microfinance institutions for the year 2014, informal deposit rate r^{di} is set at 25 percent. The steady state informal lending rate r^{bi} is set at 35 percent. At steady state the

[13] *We chose the poverty ratio because its assumed poor individuals are only concern about their current consumption and do not undergo forward looking activities*

[14] The saving rate is sourced from World Bank database
http://data.worldbank.org/indicator/NY.GNS.ICTR.ZS?locations=GH

Table 2: Calibrated Parameters

θ	2	ϕ	1.5
α	0.5	ϕ_{pi}	1.5
ϕ_y	0.5	υ^b	0.09
δ_b	0.15	k_{bf}	70
k_{df}	110	k_{bi}	60
k_{di}	100	ϵ^m	6
ϵ^d	2.5	ρ^a	0.95
ρ^{er}	0.95	s	0.25
g	0.8	υ	0.1849
β^p	0.995	β^m	0.975
μ	0.03	k_p	2
k_{kb}	5	ϵ^y	2

ratio of formal rate to informal rate gives the mark-up in the informal rate. Hence, from the steady state values of formal and informal rates, the resulting elasticity of substitution is set at 2.5 and 6 for deposit elasticity of substitution ϵ^d and lending elasticity of substitution ϵ^m respectively. The full list of calibrated parameters are shown in Table 2

4.3 Model Characteristics

This section presents the model properties and compare with observed data. The essence is to ascertain the fitness of the model and its' appropriateness for further analysis. We do this by comparing moments of the theoretical model to the estimated values from observed data. We compare only with the banking variables, however, the other variables are presented for illustrations. Figure 3 depicts the graph of retail lending rate for the observed data whiles Figure4 is the graph of series from simulated data. A qualitative inspection of the graphs for retail lending rate in both figures show that the two graphs exhibit some common features. It is evident that even though the simulated figure show some high persistence, the two graphs exhibit similar trends.

Table 3 report the standard deviation and variance decomposition for the HP-filtered series in the model. The variance decomposition provides the contribution

of the errors of the simulations of the endogenous variables in relation to exogenous shocks. Results from Table 3 shows that monetary shock explain very well changes in the monetary variables.

Table 3: Standard Deviation and Variance Decomposition

		Variance Decomposition	
VARIABLE	Standard Deviation.	z^{er}	z^{a}
r	0.4781	90.62	9.38
π	0.0134	90.99	9.01
r^{bf}	0.3347	88.45	11.55
r^{df}	0.4800	90.62	9.38
b	1.1249	85.02	14.98
d	1.0970	84.20	15.80

Another way to learn about the model characteristics is to examine the Impulse Response Function (IRF). Thus we explore the response of key variables to contraction monetary policy shock. The responses of selected aggregate variables to one standard deviation reduction of the short-term policy rate are shown in Figure 5. As the graph depicts, the model is able to replicate some of the qualitative results in the standard New Keynesian literature. A contraction monetary shock cause the policy rate to rise initially and falls gradually. This mechanism is because central banks react to output and inflation endogenously by lowering the nominal rate. As a result, the initial increase is overcompensated by the endogenous reaction due to the shock. This causes the shock to diminish along the way. Also, a contraction monetary policy causes both output and inflation to fall. Real aggregate lending rate falls as well. The combine effect of decrease in real interest rate and inflation results in an increase in nominal lending interest rate. This consequently leads to a fall in loans to the households. Following from the above description, the model has the advantage to enrich the inter-linkages between macroeconomic and financial variables including the informal sector, while able to replicate stylized facts in business cycle theory.

4.4 Interest Rate Response to Policy Shock with informal credit

In this section, we assess whether and how the transmission mechanism of monetary policy is affected by the presence of informal credit intermediation. We focus on the behaviour of interest rate by analysing the IRF to an unanticipated one standard deviation exogenous shock to the policy rate. Though the model description presents different monetary transmission channels[15], we focus mainly on interest rate channel which is the key monetary transmission channel. Here we study the modified interest rate channel which is affected by the the presence of heterogeneous agents with different degree of patience. The level of impatience as described above is depicted by agents having different discount factor.

From the model description, the effect of informal activities on interest rate in the formal sector is captured by the elasticity of substitution between formal and informal loans. As a result, we investigate how different levels of elasticity of substitution between formal and informal credits affect the way interest rate respond to monetary shock. We investigate this in two scenarios. First, we consider the situation where formal banks serve as lender of last resort to informal banks: A situation where informal bank secures extra funds from the formal bank in periods when the former is liquidity constrained. Secondly, we consider the situation where the informal is self-sufficient thus independent of the formal bank in its intermediation process.

To determine the influence of informal credit intermediation on monetary transmission, we consider the IRF for different levels of the elasticity of substitution. Graph 1 shows the graph of impulse response for lending rate for three different levels of elasticity of substitution for loans: $\epsilon^m \in \{0.5, 1, 6\}$. The graph depicts the situation where the informal bank depends on the formal bank for extra funds in situation its liquidity constrained. From the graph, it can be observed that the more elastic the elasticity of substitution, the more responsive is the formal interest rate to monetary shock. This can be explained in the following way. Formal banks respond more because it will explode the rates of informal loans due to the later dependence on the former. By this, formal banks achieve competitive advantage over informal banks in the credit market thus increasing their market share.

[15] In addition to interest rate channel, the model characteristics present other channel such as the borrowing constraint channel. This channel is the situation where an innovation in the policy rate alters the net present value of the collateral thereby changing how binding agents' constraints are

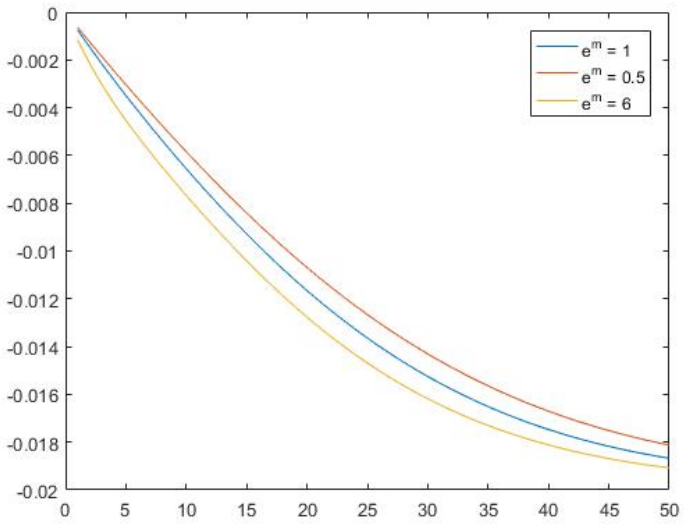

Figure 1: IRF to Monetary Shocks for ϵ^m for dependent informal bank.

On the other hand, the evidence for the situation where informal bank is self-sufficient thus independent of formal bank is different. Graph 2 show the IRF for interest rate for different level of ϵ^m when the informal bank is independent of formal bank. The graph[16] shows that interest rate is less responsive to monetary shock when elasticity is large. Contrary to scenario one, here formal bank react marginally to policy shock to enable it still have competitive edge in the credit market. This is because informal rates are not affected by the shock either directly or indirectly. Therefore, unlike scenario one where the interdependence between the banks nullify the inter-sector competition, the competition between the two banks is very intense in scenario two.

In a nutshell, the influence of informal credit activities on the behavious of interest rate reaction to monetary shocks depend on the interrelationship that exist between formal and informal banks.

[16]The IRF was compute for $\epsilon^m > 1$ i.e. $\epsilon^m \in \{2,4,6\}$ because values of $\epsilon^m \leq 1$ results in model instability

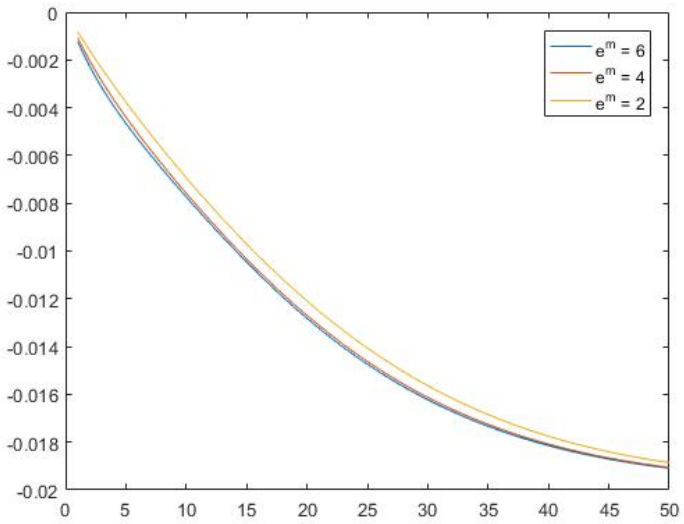

Figure 2: IRF to Monetary Shocks for ϵ^m for independent informal bank.

5 Conclusion

The study developed a DSGE model with informal credit intermediaion. The aim is to identify the effect of parallel activities of informal banks and formal banks on monetary transmission. The study found that the presences of informal intermediation affect how interest rate react to monetary policy shocks. The effect however, depends on the relationship between formal and informal bank in the intermediation process.

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Appendix

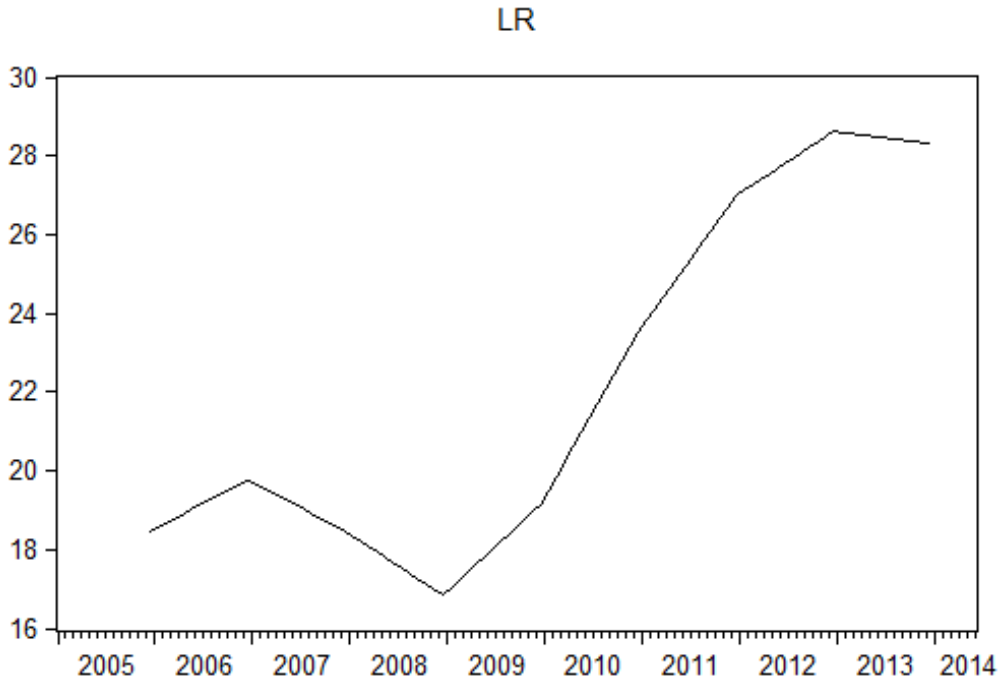

Figure 3: Lending Rate (Observed data.)

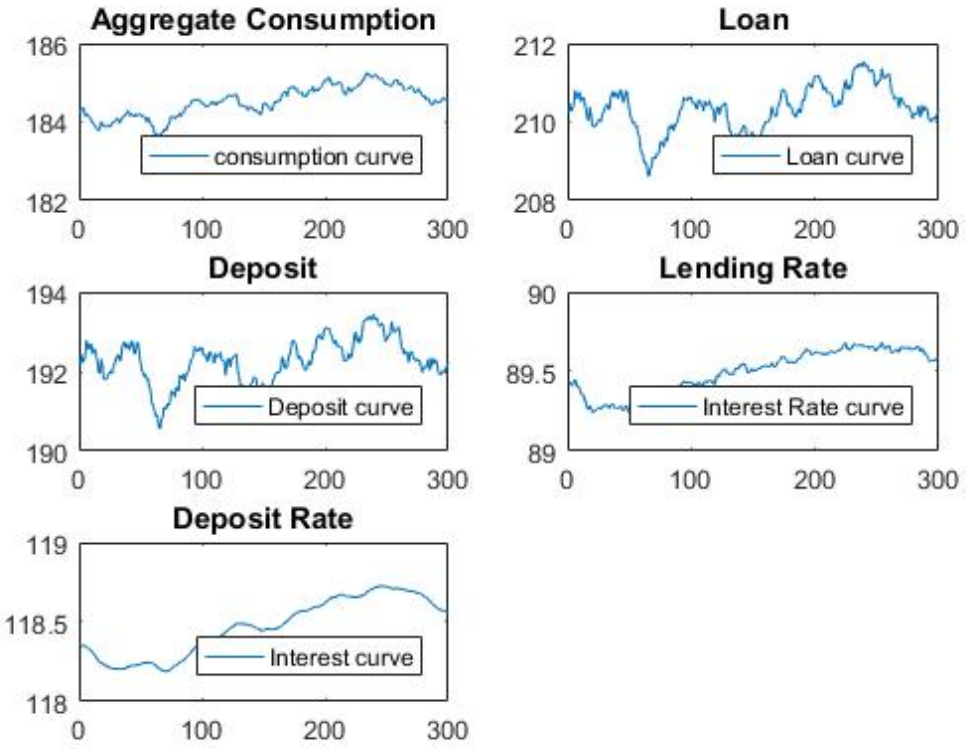

Figure 4: Graph from simulated data.

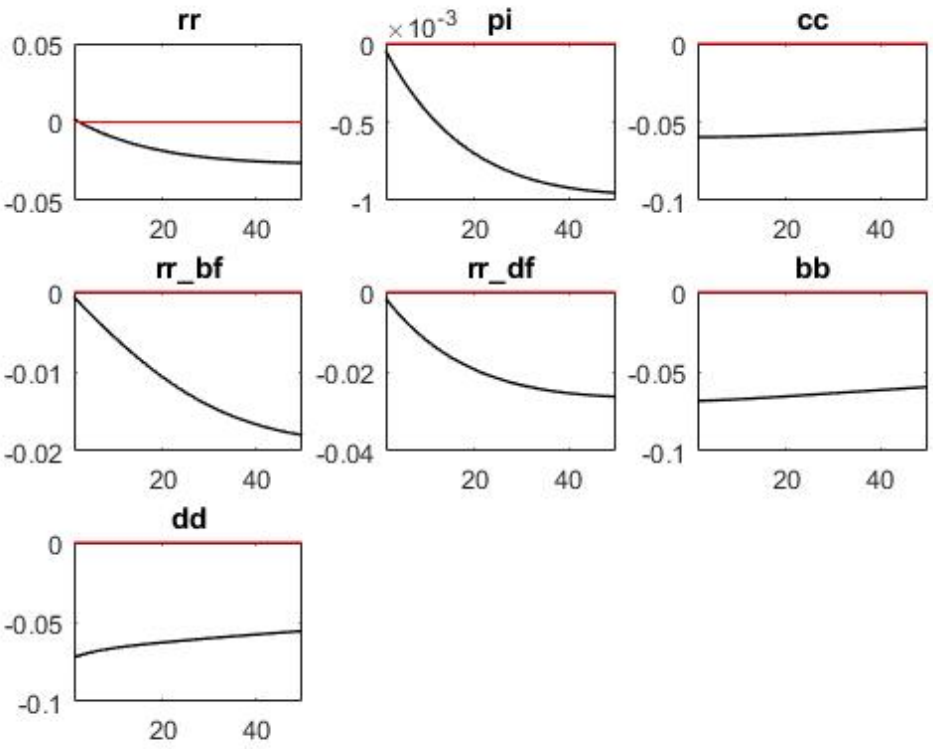

Figure 5: IRF to one S.D shock.