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Abstract

The paper posits the existence of a minimum mark-up loan interest rate threshold, which is identified using a long-term bank demand curve for excess reserves. At the threshold rate, the risk adjusted marginal revenue is equal to the marginal cost of extending loans. An excess reserves-loan (RL) equationis proposed to link excess reserves and aggregate output. The RL equation is combined with an IS equation, emphasizing the loan rate rather than the government bond rate. Together with a Phillips curve, the model is solved recursively to obtain equilibrium output and price level. The theoretical framework allows us to determine whether the unprecedented expansion of bank reserves by the Federal Reserve will engender inflation, deflation, hyperinflation or a deflationary spiral. The final outcome depends on a linear combination of five parameters and two probability regimes. The empirical results tend to support a deflation instead of an inflation regime.

JEL Codes: E41, E43, E52 and G21

Key words: excess reserves, quantitative easing, liquidity preference, deflation

1. Introduction

The recent consensus in monetary macroeconomics holds that the central bank has a policy interest rate which reacts to inflation and output gap. In this framework the role of money is subdued. However, concomitant with the change in the policy rate is the need to manage bank reserves (Dow, 2001). It was found that such reserve management can engender liquidity effects, which Carpenter and Demiralp (2008) note are the first step in the monetary transmission mechanism. Therefore, if the central bank reduces its interest rate target it is likely to inject liquidity so as to maintain a credible target; on the other hand, to increase the target rate the central bank must drain liquidity from the system.

While these operational aspects of monetary policy have usually been abstracted from in the academic literature, the monetary policy management by the U.S. Fed during the recent economic and financial crisis has renewed the interest in the role of bank reserves in monetary policy implementation (Gavin, 2009; Martin et al, 2011). Indeed, since the full-fledged outbreak of the recent crisis resulting from the fall of Lehman Brothers and AIG in the fall of 2008, the Federal Reserve has injected over $1.5 trillion of reserves into the U.S. banking system. However, as discussed by Keister and McAndrews (2009), most of this infusion has been held as excess reservesby banks.

Several authors have recently explored the reasons for the accumulation of unprecedented levels of excess reserves in the banking system. For instance, Heider et al (2009) attribute the hoarding of reserves to the existence of counterparty risk, while Freixas and Jorge (2008) propose asymmetric information problems as the determining factor in the significant build-up of excess reserves in the interbank market. Ashcraft et al (2009) provide a model to explain excess reserves as precautionary hoardings at the daily frequency. In a related study, Adrian and Shin (2009) examine liquidity as the ability of financial institutions to fund the steep discounts in market-based security prices during financial stress. In their set up the shock to security prices requires reducing leverage through rapid sales of financial assets or through borrowing. A liquidity crisis ensues as many financial market participants try to so sell assets simultaneously and rapidly. This type of asset fire sale must show up as a banking system liquidity crisis if the Fed does not intervene.

In contrast, this paper investigates the implications of a long-term aggregate demand curve for excess reserves by banks for monetary policy stabilization, and underscores the implications of the long-term liquidity preference and market power of banks for monetary policy rather than the demand for broad monetary aggregates.[1] In

[1] Our aggregative model, providing a long-period analysis, can be seen as complementary to the work of Heider et al (2009), Freixas and Jorge (2008), and Ashcraft et al (2009). Their analyses tend to focus on the short-term break down of the interbank market. On the other hand, the analysis herein looks at the demand for excess reserves using three decades of monthly data in order to identify threshold lending rates and model the macroeconomic effects.

order to achieve this task, the paper takes into consideration the stylized fact of a bank excess reserves preference curve that becomes flat at a loan rate substantially above zero. At the flat segment of the curve, the risk adjusted marginal revenue of loans equals the marginal cost of making loans. This reflects a minimum threshold loan interest rate which can be derived similarly to Freixas and Rochet (2008)as an oligopolistic mark-up rateover a benchmark interest rate (the Federal funds rate for instance) and which represents the marginal cost of funds.[2] At thislower bound loan rate bank excess reserves are seen as perfect substitutes for interest-earning loans and banks demand excess reserves voluntarily as the risk adjusted marginal revenue is equal to the marginal cost. Moreover, this perfect substitution occurs above a zero nominal interest rate. In contrast, when market loan rate rises above the threshold, the risk adjusted marginal revenue is greater than the marginal cost (the downward segment of the liquidity preference curve). In this segment any demand for excess reserves is involuntary and banks will seek to substitute interest-earning assets for excess reserves.

Keynes (1936, pp. 207-208), of course, noted the possibility that the broad monetary aggregate and government bonds could become perfect substitutes once the bond interest rate reaches zero. In contrast, the modern incarnation of the liquidity trap thesis holds that expectations play a critical role in determining the effect of monetary policy at the lower-bound interest rate (Krugman, 1998). Monetary policy could still be effective at stimulating aggregate demand at the minimum threshold once the central bank can maintain credibility by sticking to a relatively higher inflation target.However, expectations of future inflation must be backed by the ability to pay today. Therefore, when banks hoard excess reserves, and not make loans, the ability to pay today is diminished. Furthermore, given the integration of commodity markets with financial markets and the preponderance of propriety trading desks, banks might speculate in commodity markets thereby pushing up commodity prices. Oligopolistic non-financial

[2]Although not identical to the thesis of this paper, a similar notion is found in Frost (1971). Frost proposed a stable bank excess reserves curve that is kinked at a Treasury bill rate close to zero (between 0.3 and 0.5 percent). According to Frost, profit-maximizing banks incur brokerage fees (or transaction costs) which are higher than the market rate earned on Treasury bills – thus the curve is kinked at this point to signal a more elastic accumulation of excess reserves. Using an econometric procedure, Ogawa (2007) identified two factors accounting for Japanese banks' demand for excess reserves: (i) a near-zero short-term interest rate and (ii) fragile bank balance sheet. See Mounts et al (2000) for an earlier survey of the literature on the demand for excess bank reserves.

firms will then mark-up their prices over marginal cost. Thus the monetary injections could engender cost-push inflation (backward shift of the marginal cost curve) – instead of the demand-pull inflation it is intended to create – which does not solve the output problem.[3]

Therefore, the implicit proposition in this paper is the loan rate is subjected to monetary policy liquidity effects over some ranges but becomes rigid when the lower-bound oligopoly mark-up rate becomes binding. At the threshold loan rate all monetary policy liquidity effects evaporate and market loan rate becomes equal to the marginal cost of funds plus the marginal cost of making loans. Banks thus accumulate excess reserves voluntarily at this point. Further, this paper provides an analytical framework for the study of the effects of bank excess reserves on aggregate output and prices once the threshold lending rate (at a flat liquidity preference curve) is binding. The paper also develops an aggregative model that links bank loanable funds with bank liquidity preference in the presence threshold interest rates[4].

The paper is organized as follows. Section 2 presents a stylized macroeconomic model with includes bank reserves. Section 3 presents empirical evidence. Section 4 provides some concluding comments.

2. A Stylized Macroeconomic Model with Bank Reserves

This section proposes a stylized macroeconomic model which links monetary policy and the demand for excess bank reserves with macroeconomic activity and inflation. As a starting point for the derivation of the mark-up loan rate we use the Cournot model as presented by Freixas and Rochet (2008). However, we augment the basic model by including the risk of being in a shortage of excess reserves.

Let us assume the representative bank could be in three excess reserves states. State 1 – a shortage of reserves relative to required, thereby requiring the bank to borrow from the Federal funds market. In good times banks will be keen to loan out excess reserves and therefore there could be reserve shortages. A reserve shortage will occur in

[3]This point is the focus of another research paper.

[4] Unifying loanable funds and liquidity preference has been an important effort in the past (see Tsiang, 1956; Ferguson and Hart, 1980). The contribution of the model in this paper is its explicit integration of a threshold interest rate and other banking features into loanable funds and liquidity preference.

times of a bank panic. Without losing the basic conclusion assume only one penalty interest rate for state 1 – the Federal funds rate, r_F. The probability of being in a reserve deficit is denoted by θ_1. This probability is obviously related to the risk of a systemic crisis such as a run on the banks. State 2 – there is a surplus of reserves, which allows the bank to lend in the Federal funds market. Again the bank lends at r_F. The probability of being in state 2 is θ_2. State 3 – the bank has such a large build-up of excess reserves it can hoard funds in special deposits at the central bank.[5]State 3 could result because of a bank panic. The banks earn the rate of interest r_{SD} on these special deposits. The probability – which is influenced by policy – of being in state 3 is θ_3. Given that $\theta_1 + \theta_2 + \theta_3 = 1$, the expected return on excess reserves is $r_E = (\theta_2 - \theta_1) r_F + \theta_3 r_{SD}$.

The profit function, taken to be concave in loans (L_i) and deposits (D_i), of the representative bank is given by equation 1. The bank's balance sheet identity is given by 2. R_i = excess reserves, zD_i = required reserves (where z = required reserve ratio), and D_i = deposits. The inverse function forms $r_L(L)$ and $r_D(D)$ are used in the derivation process.

$$\Pi_i = r_L(L) L_i + r_E R_i - r_D(D) D_i \tag{1}$$

$$zD_i + R_i + L_i = D_i \tag{2}$$

Solving the balance sheet constraint for R_i and substituting into equation 1 gives the profit function 3. In the Cournot equilibrium the *i*th bank maximizes profit by taking the volume of loans and deposits of other banks as given. In other words, for the *i*th bank, (L_i^*, D_i^*) solves equation 3. The conditions 4 denote the aggregate quantity of loans and deposits demanded, respectively, by the entire banking sector.

$$\Pi_i = [r_L(L) - r_E] L_i - [r_D(D) - r_E(1-z)] D_i \tag{3}$$

$$L = L_i + \sum_{i \neq j} L_j \; ; \; D = D_i + \sum_{i \neq j} D_j \tag{4}$$

[5]This is the contemporary situation where banks are paid interest on special deposit of excess reserves at the Federal Reserve (Keister and McAndrews, 2009).

The first order after maximizing the profit function is given by 5. The market demand curve the bank faces is downward sloping, hence the elasticity of demand denoted by 5-2. The symbol a is the elasticity of demand for loans. There is a unique equilibrium in which bank i assumes $L_i^* = L^* / N$, where N denotes the number of commercial banks that makes up the banking sector[6]. The expression $r_L'(L)$ represents the first derivative of the loan rate with respect to L and it is simply the inverse of $L'(r_L)$.

$$\frac{d\Pi_i}{dL_i} = r_L(L) + r_L'(L)L_i - r_E = 0 \tag{5}$$

$$r_L'(L) = 1 / L'(r_L) \tag{5-1}$$

$$a = r_L \cdot L'(r_L) / L \tag{5-2}$$

Substituting 5-1 and 5-2 into 5 gives the expression 6 from which the minimum threshold rate (r_T) is obtained. The mark-up is dependent on the inverse of the product of N and the market elasticity of demand (a) for loans. As $N \to 1$ there is the case of a monopoly and the mark-up is highest, while as $N \to \infty$ one bank has an infinitesimal share of the market; the equilibrium approaches the purely competitive state in which the mark-up approaches zero.

In the threshold loan rate equation, r_F is subjected to liquidity effects and therefore can be written as $r_F(R)$ with the effect being measured by the slope $r_F'(R)$.

$$r_L(1 + \frac{1}{aN}) = r_E \text{ or } r_L(1 + \frac{1}{aN}) = (\theta_2 - \theta_1)r_F + \theta_3 r_{SD} \tag{6}$$

$$r_T = \frac{(\theta_2 - \theta_1)r_F + \theta_3 r_{SD}}{(1 + \frac{1}{aN})} \tag{7}$$

Figure 1 shows that the threshold rate occurs at r_T. This rate which is determined by market power becomes the effective supply of loans. The demand curve for excess reserves is given by R_D and it becomes flat at r_T, which represents the effective supply

[6] The use of N weighs each bank equally. This is clearly an unrealistic assumption for the purpose of making the mathematics tractable. Nevertheless, the simplification does not change the conclusion of the model. At the empirical level some authors have found evidence of interest rate pricing power at the level of the banking firm – see for instance Neumark and Sharpe (1992) and Hannan and Berger (1991).

curve (or threshold supply curve) of loans. Moreover, r_T represents the rate at which all liquidity effects have been exhausted by the central bank's monetary expansion. It is postulated here that the rate is determined by banks that possess market power. On the other hand, households and firms accept the rate as given. The commercial banks must, in turn, consider the marginal cost of funds, risk and liquidity conditions.

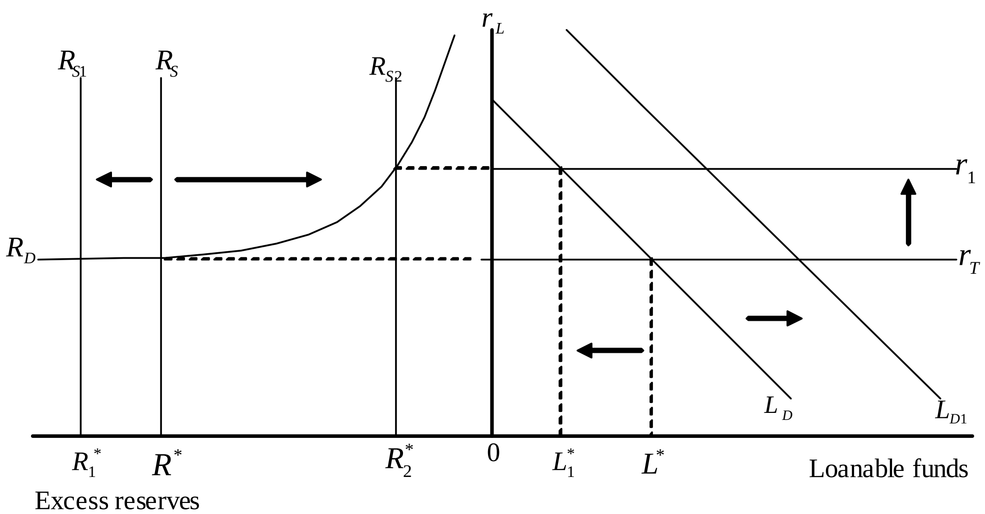

Figure 1. The threshold rate and loanable funds

The supply of reserves by the central bank is given by R_S. When $R_D = R_S$ the equilibrium quantity of reserves is determined as R^*. The demand for loans is denoted by L_D [7]. The downward sloping curve reflects the idea that an increase in the lending rate decreases the present value of future profit flows of businesses. The converse occurs when the loan rate falls. It also reflects that households' discounted future cash flows fall when the mortgage rate (or the rate on consumer credit) increases. A decline in the mortgage rate has the opposite effect on households. Substituting r_T into L_D gives the equilibrium level of credit (L^*).

[7] As an aside, albeit an important one, borrower surplus – bounded by the area under the loan demand curve and above r_T – increases when the demand for credit shifts outward. However, the surplus would diminish as the interest rate rises above the threshold as liquidity conditions tighten.

On the surface, the horizontal depiction of the loan supply curve might suggest borrowers can obtain all credit at the said rate – thus being inconsistent with a credit crunch. However, the horizontal line indicates an asymmetric determination of the lending rate, which the banks determine by market power and the public accepts. For instance, consumers do not determine credit card rates; small and medium sized businesses do not determine the rate at which they borrow. In other words, the banks set the rate with the possession of market power and offer credit at the said rate. An upward shift in the line is an indication of a credit crunch as it leads to an upward movement along the loan demand curve. In other words, all borrowers do not obtain credit. Only those who can pay the established mark-up threshold loan rate will be able to borrow at a level determined at the point where the rate intersects the demand curve.

A monetary contraction from R_S to R_{S2} leads to an increase in the lending rate above threshold to r_1. This implies the central bank's liquidity management has liquidity effects only above r_T. These liquidity effects were uncovered empirically by Carpenter and Demiralp (2008). Therefore, embedded in the threshold loan rate is the policy interest rate – r_F. A decrease in the target r_F is followed by an expansion of bank reserves in order to defend the target. On the other hand, when the r_F target is increased the central bank must diminish bank reserves to keep the target credible. The shocks to excess reserves are demonstrated by a movement of a vertical reserve supply curve (figure 1) along the demand curve. Consequently, credit is contracted from L^* to L_1^*. On the other hand, a monetary expansion from R_S to R_{S1} leads to no further decrease in the lending rate as the minimum threshold rate is now binding. Credit expansion stops at L^* and excess reserves are accumulated voluntarily. Therefore, once the threshold rate is reached credit intermediation would require that policies directly stimulate the demand for loans along this rate. The demand curve for loans shifts out from L_D to L_{D1}.

Given the stylized facts and the diagrammatic exposition (see figures 3 and 4), it is reasonable to express the banks' demand for excess reserves as the following reciprocal model

$$r_L = r_T + \beta\left(\frac{1}{R^*}\right) \tag{8}$$

Note that the threshold minimum rate is the asymptote. β is a coefficient and R^* is the equilibrium level of excess reserves as shown in figure 1, from which we can form the following relationship between excess reserves and the demand for loans.

$$r_T + \beta\left(\frac{1}{R^*}\right) = -ar_L + bY \tag{9}$$

The demand for loans is given by the following simple double-log function $L_D = -ar_L + bY$, which is chosen for the purpose of algebraic convenience. a = the public's elasticity of demand for loans; b = the public's income elasticity of demand for loans; and Y = aggregate output. Therefore, it is possible to rewrite equation 9 as

$$\frac{(\theta_2 - \theta_1)r_F(R^*) + \theta_3 r_{SD}}{(1 + \frac{1}{aN})} + \beta\left(\frac{1}{R^*}\right) = -ar_L + bY \tag{10}$$

Equation 10 can be solved for r_L to obtain the RL equation in terms of Y, R^* and the exogenous parameters of the model. One of the attractive features of this equationis that it introduces a microeconomic term into a macroeconomic function.

In order to analyze the implications of a lower bound in the loan interest rate at the macroeconomic level, we use a traditional IS equation which links the expected real interest rate with the level of economic activity

$$Y_t = A - \alpha_r(r_L - \pi_{t-1}) \tag{11}$$

From equation 11, A is determined by the autonomous components of consumption and government spending, α_r represents the interest rate elasticity of output and π_{t-1} represents aggregate price inflation in the previous time period. We assume that the equation of motion for aggregate price inflation is determined by the following Phillips curve relationship

$$\pi_t = \lambda\pi_{t-1} + \gamma y_t \tag{12}$$

Where π_t denotes the inflation rate in the present period and y_t is the output gap between trend output ($\overline{Y}$) and equilibrium output, which we will solve for later in the paper; thus $y_t = Y^* - \bar{Y}$, with λ representing the degree of inflation persistence in the economy.

Solving for r_L in equation 10 and setting it equal to the IS equation gives the reduced form solution for aggregate output Y^*. The equilibrium output is given by equation 13, which shows that excess reserves influence aggregate output via changes in the funds rate and the composite elasticity.

$$Y^* = \frac{(\theta_2 - \theta_1) r_F (R^*) + \theta_3 r_{SD}}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})} + \left(\frac{\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})} \right) R^{*-1} + \left(\frac{1}{\alpha_r (\frac{b}{a} + \frac{1}{\alpha_r})} \right) A + \left(\frac{1}{\frac{b}{a} + \frac{1}{\alpha_r}} \right) \pi_{t-1} \quad (13)$$

In order to obtain the output dynamics, take the total differential of equation 13. Note that $r_F'(R^*)$ is the slope of the bank liquidity preference curve in the Federal funds market. This slope is given by $-\alpha / R^{*2}$. Express dY^*, dR^*, dA and $d\pi_{t-1}$ in discrete form, respectively, as follows $\Delta Y^*, \Delta R^*, \Delta A$ and $\Delta\pi_{t-1}$; and note that $\Delta Y^* = Y_t - Y_{t-1}$. We can assume a partial adjustment framework as follows: $Y_t - Y_{t-1} = \delta(\bar{Y} - Y_{t-1})$. Substituting the slope and the discrete forms and taking into consideration the partial adjustment mechanism give equation 15.

$$dY^* = \frac{(\theta_2 - \theta_1) r_F'(R^*)}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})} \cdot dR^* - \left(\frac{\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})} \right) R^{*-2} \cdot dR^* + \left(\frac{1}{\alpha_r (\frac{b}{a} + \frac{1}{\alpha_r})} \right) dA + \left(\frac{1}{\frac{b}{a} + \frac{1}{\alpha_r}} \right) d\pi_{t-1} \quad (14)$$

$$Y_t = (1-\delta) Y_{t-1} + \delta \bar{Y} - \left(\left\{ \frac{\alpha(\theta_2 - \theta_1)}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})} + \frac{\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})} \right\} \frac{1}{R^{*2}} \right) \Delta R_t^* + \left(\frac{1}{\alpha_r (\frac{b}{a} + \frac{1}{\alpha_r})} \right) \Delta A_t + \left(\frac{1}{\frac{b}{a} + \frac{1}{\alpha_r}} \right) \Delta\pi_{t-1} \quad (15)$$

Let

$$\alpha_1 = -\left\{ \frac{\alpha(\theta_2 - \theta_1)}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})} + \frac{\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})} \right\} \frac{1}{R^{*2}}$$

$$\alpha_2 = \frac{1}{\alpha_r(\frac{b}{a} + \frac{1}{\alpha_r})}$$

$$\alpha_3 = \frac{1}{\frac{b}{a} + \frac{1}{\alpha_r}}$$

$$Y_t = (1-\delta)Y_{t-1} + \delta\overline{Y} - \alpha_1 \Delta R_t^* + \alpha_2 \Delta A_t + \alpha_3 \Delta \pi_{t-1} \tag{16}$$

Equation 16 allows us to solve for the time path of Y_t and to derive the dynamic multipliers to study the effect of excess bank reserves and the autonomous components. For an initial value of output (Y_0) and $1-\delta < 0$ we obtain the following solution by the recursive method (equation 17). The dynamic multiplier showing the effect on output (for *s* future periods) given a change in ΔR is given by equation 18. The equation has an interesting feature because the equilibrium level of reserves, R^*, stays in the equation. This allows us to calculate the effect of liquidity injections (or contractions) at the threshold level.

$$Y_t = \overline{Y} + (1-\delta)^t Y_0 - \alpha_1 \sum_{i=0}^{t-1} (1-\delta)^i \Delta R_{t-i} + \alpha_2 \sum_{i=0}^{t-1} (1-\delta)^i \Delta A_{t-i} + \alpha_3 \sum_{i=2}^{t-1} (1-\delta)^i \Delta \pi_{t-i-1} \tag{17}$$

$$\frac{\partial Y_s}{\partial(\Delta R)} = -\alpha_1 (1-\delta)^i = -\left(\left\{ \frac{\alpha(\theta_2 - \theta_1)}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})} + \frac{\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})} \right\} \frac{1}{R^{*2}} \right) (1-\delta)^i \tag{18}$$

Another feature of equation 18 is the effect of the reserve injection depends on two regimes. First, there is regime 1 in which $\theta_2 < \theta_1$. In this regime bank lending is strong and there is a greater likelihood of a reserve deficit. Here if *N* is sufficiently large (we have competition rather than oligopoly) and α is also large enough, we can have the situation in which the stimulation of bank reserves feeds through to higher output. Otherwise, regime 2, whereby $\theta_2 > \theta_1$, holds. There is weak lending and surplus of excess reserves. Therefore, the excess reserves are consistent with a decreased in output and therefore employment. Figure 2 below shows the simulation of these possibilities for different levels of excess reserves in the two regimes over eight time periods (*s* = *8*). The diagram suggests, given the same parameters, in each regime increasing reserves will diminish the response once the threshold interest rate is binding.

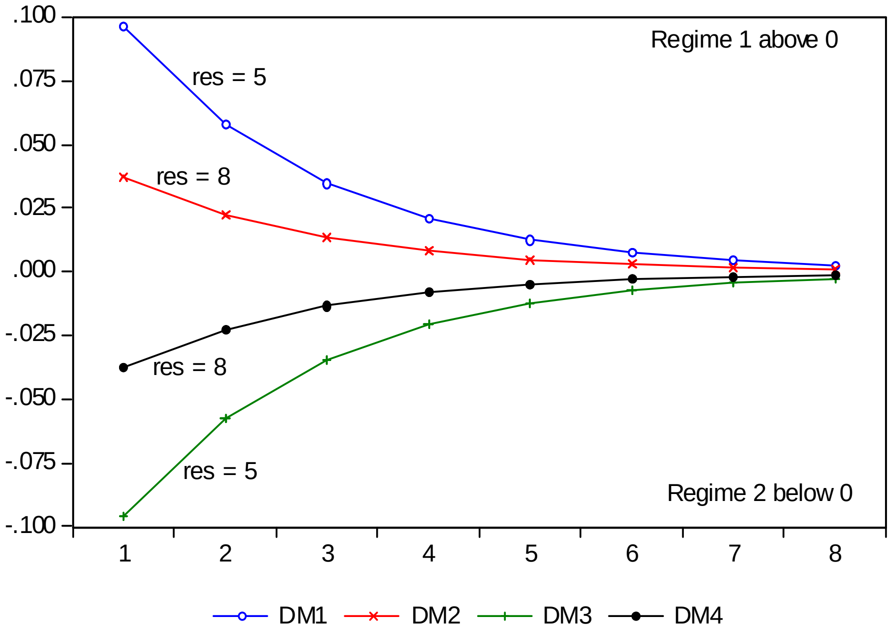

Figure 2. Dynamic multipliers (DM) showing output response for two lending/reserves regimes

We now need to examine how inflation will adjust given changes in excess reserves. This requires substituting equation 13, the equilibrium output, into the equation which shows price adjustments, equation 12. From equation 13 let

$$M = \frac{(\theta_2 - \theta_1) r_F (R^*) + \theta_3 r_{SD}}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})}$$

and

$$\phi = \frac{\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})}$$

Therefore, equation 13 can be rewritten as

$$Y_t^* = M + \phi R_t^{*-1} + \alpha_2 A + \alpha_3 \pi_{t-1} \tag{20}$$

Substituting equation 20 into 12 gives

$$\pi_t = \gamma(M - \overline{Y}) + (\lambda + \alpha_3\gamma)\pi_{t-1} + \gamma\phi R_t^{*-1} + \alpha_2\gamma A \tag{21}$$

Alternatively equation 21 can be rewritten as

$$\pi_t = \gamma\left(\frac{(\theta_2 - \theta_1) r_F(R^*) + \theta_3 r_{SD}}{a(\frac{b}{a} + \frac{1}{\alpha_r})(1 + \frac{1}{aN})} - \overline{Y}\right) + (\lambda + \alpha_3\gamma)\pi_{t-1} + \frac{\gamma\beta}{a(\frac{b}{a} + \frac{1}{\alpha_r})} R_t^{*-1} + \alpha_2\gamma A \tag{22}$$

Equation 22, a dynamic equation, allows us to analyze the effect of excess reserves on inflation. The dynamic multiplier (DM) can be visualized as the product of the following two derivatives. As noted earlier $r_F'(R^*) = -\alpha / R^{*2}$. Therefore,

$$DM = \left(\frac{\partial \pi_t}{\partial R_t^*}\right)\left(\frac{\partial \pi_t}{\partial \pi_{t-1}}\right)^t = -\left(\frac{1}{a(\frac{b}{a} + \frac{1}{\alpha_r})}\left\{\frac{\alpha(\theta_2 - \theta_1)}{(1 + \frac{1}{aN})} + \beta\right\}\left(\frac{\gamma}{R_t^{*-2}}\right)\right)(\lambda + \alpha_3\gamma)^t \tag{23}$$

Equation 23 suggests four possible price level outcomes in the two regimes. These are the outcomes given a specific amount of increase or decrease in excess bank reserves. Table 1 below indicates the possible scenarios, which are dependent on the relative size of the various parameters.

Table 1. Price level outcomes given an increase in excess reserves

	Regime 1: $\theta_2 < \theta_1$	Regime 2: $\theta_2 > \theta_1$
$0 < \lambda + \alpha_3\gamma < 1$	Inflationary event but price level returns to equilibrium	Deflationary event but price level returns to equilibrium
$\lambda + \alpha_3\gamma > 1$	Aggregate prices explode; hyperinflation	A deflationary spiral results; prices explode downward

Crucial to the inflation or deflation situation is the term $\lambda + \alpha_3\gamma$, which implies that five parameters are important for driving the inflationary or deflationary process. These parameters are *a*, *b*, α_r, λ and γ. As noted earlier, a = the public's elasticity of demand for loans; *b* = the public's income elasticity of demand for loans; α_r is the output sensitivity to the lending rate; λ = the degree of inflation persistence in the economy; and

γ = a measurement of the output gap and inflation relationship. The linear combination of these parameters together with the two probability regimes provide insight into the extent to which the unprecedented expansion of bank reserves can engender aggregate output and price changes.

3. Empirical Evidence

Let us now take a look at the empirical evidence for the existence of a lower-bound loan interest rate. Figure 3 presents a scatter plot of the prime loan interest rate and excess reserves. As it can be easily observed, the relationship between these two variables features a significant nonlinearity as the one suggested by the theoretical model discussed in the previous section. Accordingly, the picture suggests the existence of alower bound loan rate of approximately 7%, around which point the curve becomes flat.This stylized fact becomes particularly striking when the sample is enlarged to include the recent crisis period where the threshold occurs at around 4%[8].

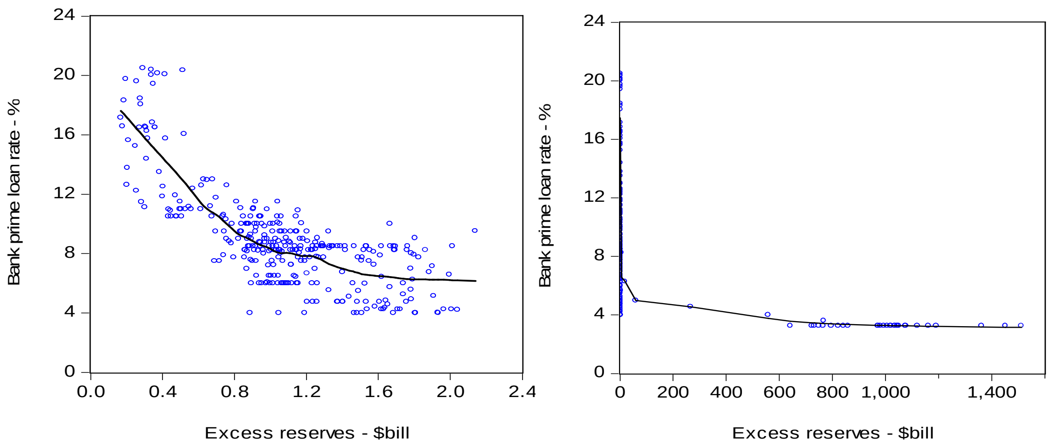

Figure 3. Loan market liquidity preference – monthly data 1980:1–2006:12 (left panel) and1980:1-2011:5 (right panel). Data source: Federal Reserve Economic Data (http://research.stlouisfed.org/fred2/)

As discussed in the previous section, the benchmark interest rate (assumed here to be represented by the effective federal funds rate) is embedded in the lower bound loan

[8]The liquidity preference curves are all extracted from scatter plots using the method of locally weighted regressions with a smoothing parameter of 0.4 (see Cleveland, 1993; 1979). Two outliners were removed – those are September 2001 and August 2003. Removing the outliers does not affect the pre-2007 interest thresholds. Instead including the outliers makes the threshold rate more conspicuous.

rate. If the loan interest rate is a mark-up over the marginal cost of funds – the Federal funds rate – then we should observe a threshold behavior when examining a scatter plot between excess reserves and the funds rate. This possibility is illustrated by figure 4. It is clear that the flat segment of the pre- and post-crisis curves occurs below the threshold obtained when the prime lending rate is used (figure 3). This implies a stable relationship between the loan-funds rate spread and excess reserves.

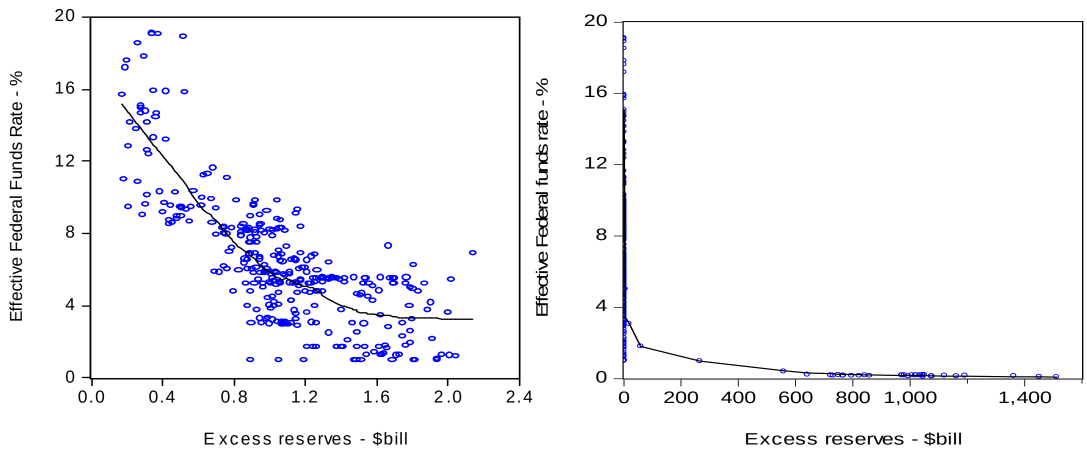

Figure 4. Federal funds market liquidity preference – monthly data. 1980:1 – 2006:12 (left panel), 1980:1 to 2011:5 (right panel). Data source: Federal Reserve Economic Data (http://research.stlouisfed.org/fred2/)

The theoretical framework allows us to have a structural method in order to study to what extent and in what direction liquidity effects exert an influence on key macroeconomic variables. The reciprocal functional form of the liquidity preference curve allows us to have a slope of $r_F'(R) = -\alpha / R^2$. This slope is our structural measure of liquidity effects. Changes in this slope reflect central bank open market operations or more aggressive policies such as quantitative easing. Changes in bank liquidity owing to monetary policy, therefore, result in movements along the reciprocal liquidity preference curve but not a shift of this curve. On the other hand, shifts in the liquidity preference curve will reflect changes in bank liquidity preference. The shift in the curve may be endogenous to various macroeconomic variables and it can also exert influences. However, changes in the slope are reflective of central bank policy actions and therefore they are exogenous. Although different from the VAR approach, our method of identifying liquidity effects can be seen as complementary to that of Carpenter and Demiralp (2008).

The approach of this paper requires an approximation for α, which can be estimated by an empirical reciprocal regression function: $r_F = r_T + \alpha / R + \varepsilon^D$. ε^D is the measure of the shifts or shocks of bank liquidity preference. We estimated α by least squares for the period 1980: Jan – 2011: May[9]. The coefficient estimate was found to be 3.3916 with a t-value of 7.74. The federal funds market threshold (r_T) was estimated to be 2.086 with a t-statistic of 4.44 (robust standard errors). Once α is estimated we can approximate the liquidity effect (LIQ) for each time period. Since LIQ is exogenous we can include this measure in a series of bivariate regressions to measure its influence.

The following bivariate regression is estimated.

$$X_t = c_0 + \sum_{i=1}^{p} c_i X_{t-i} + dLIQ_t + \varepsilon_t$$

The regression results are presented in table 2 for two time periods – 1980: Jan to 2006: Dec and 2007: Jan to 2011: May. X_t represents the set macroeconomic variables reported in table 2. We do not report the coefficient of the lagged dependent variables. The final parsimonious regression model was decided based on Wald F-tests on a general model with lags of both the dependent and key independent variable (LIQ). Robust standard errors were calculated in each case. In both periods the liquidity effect is associated with price decrease instead of inflation measured as consumer price index (CPI) and producer price index (PPI). This result is statistically significant for each period. The deflation of prices, captured by the higher negative coefficient, is faster for the post-2006 period.

[9]In future research we can estimate this coefficient with a time-varying method such as rolling regressions or the state space method.

Table 2. Liquidity effect on selected macroeconomic variables

Macro variable	**Coefficient estimate showing effect of LIQ; 1980: Jan – 2006: Dec**	**Coefficient estimate showing effect of LIQ; 2007: Jan – 2011: May**
Inflation - CPI	**-0.0051**; t-stat = -4.22; p-val = 0.000; two significant lagged dependent terms	**-0.1057**; t-stat = -2.15; p-val = 0.035; two significant lagged dependent terms
Inflation – PPI	**-0.0053;** t-stat = -2.52; p-val = 0.0121; two significant lagged dependent terms	**-3.448;**t-stat = -1.72; p-val = 0.092; two significant lagged dependent terms
Unemployment	**-0.0018**; t-stat = 1.13; p-val = 0.257; one significant lagged dependent term	**0.334**; t-stat = 1.53; p-val = 0.130; one significant lagged dependent term
Δ(Loans)	**0.1282**; t-stat = 3.55; p-val = 0.000; one significant lagged dependent term	**-35.7**; t-stat = -2.47; p-val = 0.016; one significant lagged dependent term
Δ(Deposits)	**0.0376**; t-stat = 2.19; p-val = 0.028; one significant lagged dependent term	**8.45**; t-stat = 2.06; p-val = 0.045; one significant lagged dependent term
Mortgage rate	**-0.0033**; t-stat = -0.87; p-val = 0.385; one significant lagged dependent term	**-0.1902**; t-stat = -3.28; p-val = 0.002; one significant lagged dependent term
Moody_AAA	**-0.0022**; t-stat = -0.82; p-val = 0.42; one significant lagged dependent term	**-0.0723**; t-stat = -1.48; p-val = 0.146; one significant lagged dependent term
Moody_BAA	**-0.0031**; t-stat = -1.3; p-val = 0.194; one significant lagged dependent term	**-0.048**; t-stat = -0.87; p-val = 0.389; one significant lagged dependent term

For the period 1980 to 2006 the liquidity effect appears to reduce unemployment but by an amount that is very small and statistically insignificant. However, the unemployment rate tends to be positively related with LIQ in the period 2007 to May 2011. This result is consistent with the deflation instead of inflation regime. LIQ tends to increase lending, Δ(Loans), in the pre-2007 period, while lending declined substantially given the liquidity effect. There is a consistent increase in deposits, Δ(deposits), albeit a stronger increase after 2006. One of the justifications of quantitative easing, which has the effect of increasing bank reserves significantly, is that it diminishes interest rates at the longer end of assets. We find evidence in support of this whereby the mortgage rate, Moody's AAA and Moody's BAA bond yields have declined substantially after 2006 given changes in the measured liquidity effect.

4. Conclusion

This paper analyzed the effect of bank reserve expansion in the presence of aggregate bank liquidity preference and a mark-up threshold loan rate. Although there is a large literature on various monetary transmission mechanisms, this line of exploration does not exist in the present literature. Moreover, this paper takes the loan rate as being determined by oligopolistic forces instead of a competitive loanable funds mechanism. This line of analysis comes in the presence of unprecedented expansion of excess bank reserves by the Federal Reserve in spite of the conventional wisdom which holds that the Federal Reserve uses the Federal funds rate as its main instrument since the late 1980s (Meulendyke, 1998).

The paper examined the effects of reserve expansion when a threshold lending rate, identified by a flat bank liquidity preference curve, is binding. Therefore, instead to focusing on the demand for broad monetary aggregates, this study underscores that the behavior of banks, as it relates to interest rate mark-up and liquidity preference, is crucial for the functioning of the monetary transmission mechanism. Moreover, using a long data set, long-term liquidity preferences are identified; thus distinguishing this study from those which perform short period analyses of the liquidity build-up in the interbank markets of Europe and the United States. The paper proposed a model which helps us to understand whether quantitative easing will engender a short period deflation episode, a deflationary spiral, inflation or hyperinflation. In addition, the model shows how liquidity preferences and loanable funds can be integrated at the level of the banking firm. The empirical results suggest that excess reserves are associated with a deflationary episode instead of an inflationary environment.

References

Adrian, Tobias and Hyun Song Shin (2009). ‘Money, liquidity and monetary policy.’ *American Economic Review: Papers & Proceedings*, Vol. 99 (2): 600-605.

Ashcraft, Adam; James McAndrews and David Skeie (2009). ‘Precautionary reserves in the interbank market.’ *Staff Report No. 370*, Federal Reserve Bank of New York.

Cleveland, William (1993). *Visualizing Data*. Summit, NJ: Hobart Press.

Cleveland, William (1979). ‘Robust locally weighted regression and smoothing scatterplots.’ *Journal of the American Statistical Association*, Vol. 74: 829-836.

Carpenter, Seth and Selva Demiralp (2008). ‘The liquidity effect in the federal funds market: evidence at the monthly frequency.’ *Journal of Money, Credit and Banking*, Vol. 40 (1): 1-24.

Dow, Jr., James (2001). ‘The demand for excess reserves.’ *Southern Economic Journal*, Vol. 67 (3): 685-700.

Ferguson, J. David and William Hart (1980). ‘Liquidity preference or loanable funds: interest rate determination in market disequilibrium.’ *Oxford Economic Papers*, Vol. 32 (1): 57-70.

Freixas, Xavier and Jean-Charles Rochet (2008). *Microeconomics of Banking*, 2nd edition. Cambridge, MA: MIT Press.

Freixas, Xavier and Jose Jorge (2008). ‘The role of interbank markets in monetary policy: a model with rationing.’ *Journal of Money, Credit and Banking*, Vol. 40 (6): 1151-1176.

Frost, Peter (1971). ‘Banks’ demand for excess reserves.’ *Journal of Political Economy*, Vol. 79 (4): 805-825.

Gavin, William (2009). ‘More money: understanding recent changes in the monetary base.’ *Federal Reserve Bank of St. Louis Review*, March/April: 49-59.

Hannan, Timothy and Allen Berger (1991). ‘The rigidity of prices: evidence from the banking industry. *American Economic Review*, Vol. 81 (4): 938-945.

Heider, Florian, Marie Hoerova and Cornelia Holthausen (2009). ‘Liquidity hoarding and interbank market spreads: the role of counterparty risk.’ *Working Paper Series No. 1126*, European Central Bank.

Keister, Todd and James McAndrews (2009). ‘Why are banks holding so many excess reserves?’ Federal Reserve Bank of New York Staff Report No. 380.

Keynes, John M. (1936). *The General Theory of Employment, Interest and Money*. New York: Harcourt, Brace & World, Inc.

Krugman, Paul (1998). ‘It’s baaack: Japan’s slump and the return of the liquidity trap.’ *Brookings Papers on Economic Activities*, Vol. 2: 137-205.

Martin, Antoine; James McAndrews and David Skeie (2011). ‘A note on bank lending in times of large bank reserves.’ Federal Reserve Bank Staff Report No. 497.

Meulendyke, Ann Marie (1998). *U. S. Monetary Policy and Financial Markets*. New York: Federal Reserve Bank of New York.

Mounts, Jr., WM. Stewart, Clifford Sowell and Atul Saxena (2000). ‘An examination of country member bank cash balances of the 1930s: a test of alternative explanations.’ *Southern Economic Journal*, Vol. 66 (4): 923-941.

Neumark, David and Steven Sharpe (1992). ‘Market structure and the nature of price rigidity: evidence from the market for consumer deposits.’ *Quarterly Journal of Economics*, Vol. 107 (2): 657-680.

Ogawa, Kazuo (2007). ‘Why Japanese banks held excess reserves: the Japanese experience of the late 1990s.’ *Journal of Money, Credit and Banking*, Vol. 39 (1): 241-257.

Tsiang, S. C. (1956). ‘Liquidity preference and loanable funds theories, multiplier and velocity analyses: a synthesis.’ *American Economic Review*, Vol. 46 (4): 539-564.