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in an Optimal Monetary Policy  
Framework

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# THE USE OF RESERVE REQUIREMENTS IN AN OPTIMAL MONETARY POLICY FRAMEWORK\*

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BANCO DE LA REPÚBLICA

**ABSTRACT.** We analyse three models to determine the conditions under which reserve requirements are used as a part of an optimal monetary policy framework in an inflation targeting regime. In all cases the Central Bank (CB) minimizes an objective function that depends on deviations of inflation from its target, the output gap and deviations of reserve requirements from its optimal long term level. In a closed economy model we find that optimal monetary policy implies setting reserve requirements at their long term level, while adjusting the policy interest rate to face macroeconomic shocks. Reserve requirements are included in an optimal monetary policy response in an open economy model with the same CB objective function and in a closed economy model in which the CB objective function includes financial stability. The relevance, magnitude and direction of the movements of reserve requirements depend on the parameters of the economy and the shocks that affect it.

*Key words.* Reserve Requirements, Inflation Targeting, Monetary Policy.

*JEL Classification.* E51, E52, E58.

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## 1. INTRODUCTION

Some inflation targeting countries like Brazil, Colombia and Peru, have used reserve requirements on domestic deposits as a macro-prudential policy tool aimed at increasing lending interest rates, reducing credit growth and curbing excessive private sector leverage during the expansionary phase of the credit cycle (Garcia-Escribano et al. (2011)). In turn, those Central Banks have decreased reserve requirements to provide liquidity and reduce financial system interest rates in the contractionary phase of the credit cycle. However, these shifts in reserve requirements may have an effect on other macroeconomic variables and other Central Bank (CB) objectives. This document explores the conditions in which reserve requirements are useful tools in addition to the policy interest rate within an Inflation Targeting (IT) regime.

We find that an inflation targeting CB minimizing the output gap, the deviations of inflation from its target and financial distortions will not actively use reserve requirements in addition to the policy interest rate when it operates in a closed economy with only one transmission mechanism (the aggregate demand). In contrast, reserve requirements do play a role in an open economy in which there is an exchange rate transmission mechanism. In this case, optimal monetary policy involves the use of reserve requirements if inflation deviates from its target and if the ratio between the effects of the policy interest rate and the reserve requirements on the exchange rate differs from the ratio between the effects that those two instruments have on aggregate demand. In this circumstances, the CB may exploit the difference between the transmission mechanisms of the two policy measures, adjusting reserve requirements to improve the trade-offs between inflation and the output gap that emerge when only the policy interest rate is used.

Reserve requirements may also play a role as a monetary policy tool when there is an additional objective in the CB loss function, e.g. private sector leverage. Here, reserve requirements may improve the trade-offs between inflation, the output gap and leverage as long as the ratio between the effects of the policy rate and reserve requirements on the lending rate differs from the ratio between the effects of those policy variables on the deposit interest rate. In all cases, the importance of reserve requirements as a policy instrument depends on the parameters of the economy. We evaluate the relevance of reserve requirements as a monetary policy tool in Colombia based on the empirical evidence on the parameters of the economy found in other research papers.

Some of our results are in line with those found by Cecchetti and Kohler (2011), who examine the substitutability between the policy interest rate and capital requirements. The authors find that these policy measures are substitutes in a closed economy in which the CB loss function includes inflation and the output gap. That is, when one of these instruments is fixed at its optimal value, the equilibrium outcome cannot be improved by adjusting the other. When financial stability is included in the CB objective function, both tools are part of the optimal policy. This implies that there needs to be coordination between monetary and macro-prudential policy.

## 2. WHAT DO WE KNOW ABOUT THE EFFECTS OF RESERVE REQUIREMENTS IN AN INFLATION TARGETING REGIME?

If bank deposits and CB credit are perfect substitutes as sources of funding, shifts in reserve requirements will not affect the cost of funds for banks when the CB stabilizes the policy interest

rate, as it typically does in an IT regime. Hence, credit supply and lending interest rates remain stable. However, deposit demand by banks falls and so do deposit interest rates. Thus the interest rate spread widens through lower deposit rates (e.g. Betancourt and Vargas (2009)).

In contrast, when CB credit and bank deposits are imperfect substitutes as sources of funds for banks, reserve requirements may have an effect on loan supply and the lending interest rate. For example, this may be due to the uncertainty about the future policy interest rate and the resulting risk that banks face when loan or deposit maturity differs from the maturity of the CB credit (Betancourt and Vargas (2009)). In this case, an increase in reserve requirements raises the lending interest rate and has an uncertain impact on the deposit interest rate<sup>1</sup>. Therefore, the final effect of reserve requirement on credit volume in an IT regime depends on the substitutability between bank deposits and CB credit.

Vargas et al. (2010) estimate long term relationships between several lending and deposit interest rates in Colombia, and their determinants, including the policy interest rate, the slope of the yield curve, other supply and demand variables, and reserve requirements. The authors found: i) positive long term effects of reserve requirements on commercial, prime and treasury lending rates, as well as on average CD rates and rates of CDs longer than one year; and ii) no statistically significant effects on consumer, mortgage and average lending rates, nor on the interest rates of saving accounts and CDs with maturity shorter than one year.

Bustamante et al. (2012) estimate a VARX for Colombia with data from 1994Q1 to 2011Q3 to study the transmission of shocks to reserve requirements and policy interest rate to financial system interest rates and a set of macroeconomic variables. The endogenous variables in the VARX model are ordered so that the policy interest rate shock is identified by a Cholesky decomposition<sup>2</sup>. Reserve requirements are introduced as an exogenous variable and are measured as bank reserves as a percentage of bank liabilities.

The authors find that shocks to the policy interest rate and to reserve requirements reduce GDP, inflation and bank loans, while increasing lending and deposit interest rates. The econometric estimation suggests that a 100 b.p shock to the policy interest rate generates stronger reactions in GDP, inflation and bank loans than a shock of the same size to reserve requirements. This might be due to the compensatory endogenous response of the overnight interbank interest rate to the reserve requirements shock. To control for this endogeneity, the authors consider a simultaneous shock of 100 b.p to the interbank interest rate and reserve requirements. Results show a low contribution of the reserve requirement shock to the responses of macroeconomic variables.

In the same line, Glocker and Towbin (2012a) estimate a VAR with Brazilian data. The results show that positive shocks to the policy interest rate and to reserve requirements reduce domestic

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<sup>1</sup>A rise in reserve requirements increases banks' demand for liquidity from the CB. This raises the exposure of banks to interest rate risk when the CB loans are short term. Hence, bank loans become costlier (do to higher interest rate risk) and deposit demand by banks goes up. The first effect pushes the lending interest rates up. The second one increases deposit interest rates, (partially) offsetting their decline due to the fact that reserve requirements make deposits less attractive as sources of funds.

<sup>2</sup>The ordering is as follows: real GDP, annual CPI inflation, real bank loans, overnight interbank interest rate, lending interest rate, deposit (CD) interest rate and monetary base. GDP, real bank loans and monetary base are included in logarithms. This specification assumes that the monetary authority observes the shocks at the same time as other macroeconomic variables when setting the policy interest rate. Given the lags of macroeconomic data this might not be adequate.

credit. However, unlike the shock to the policy interest rate, a positive shock to reserve requirements depreciates the currency, improves the current account and increases inflation. Therefore, the authors suggest that reserve requirements can complement the policy interest rate tool in preserving financial stability, but cannot substitute it for controlling inflation. In a theoretical work (Glocker and Towbin (2012b)), the same authors analyze the effects of reserve requirements in a dynamic stochastic general equilibrium model for a small open economy. They find that reserve requirements are useful to control inflation only if financial frictions are important. Further, reserve requirements lead to substantial improvements in welfare if the CB includes financial stability in its loss function. Additionally, the results imply that, in contrast to the policy interest rate, reserve requirements are more effective to stabilize the product and the inflation when there is debt denominated in foreign currency.

Garcia-Escribano et al. (2011) evaluate the effectiveness of reserve requirements to contain credit growth using data from Peru, Brazil, Colombia, Chile and Mexico. They follow two methods: an event analysis and a dynamic VAR with panel data. According to their results, reserve requirements have a moderate and transitory impact on credit growth. The event analysis shows that in countries that used reserve requirements and other macro-prudential measures, credit growth was reduced by 1% in the following month<sup>3</sup>. However, this impact was moderate since, after 4 months, credit started to grow at the same pace as before the implementation of the measure. Additionally, the results indicate that, unlike general reserve requirements, marginal reserve requirements have negligible effects.

### 3. WHEN SHOULD RESERVE REQUIREMENTS BE USED AS A POLICY INSTRUMENT IN AN INFLATION TARGETING REGIME?

**3.1. A Closed Economy Model (model I).** In a stylized, closed economy IT model, reserve requirements play no role as an independent monetary policy tool besides the interest rate. For example, in the simple IT model presented in Walsh (2002), the CB optimally determines its policy acknowledging the short term trade-off that may emerge between inflation and the output gap. This simple model may be extended to include reserve requirements as a monetary policy instrument. The introduction of reserve requirements implies two considerations.

First, reserve requirements affect inflation and the output gap through their impact on lending and deposit interest rates, and, thereby on aggregate expenditure:  $x = x(i, z)$ . This is a version of the IS curve in which the output gap is a function of the policy interest rate ( $i$ ) and reserve requirements ( $z$ ). According to the discussion of the foregoing section on the effects of reserve requirements in a IT regime, an increase in reserve requirements raises lending interest rates and reduces aggregate demand. However, at the same time, a rise in reserve requirements has an ambiguous effect on deposit interest rates. In fact, it may decrease them. If the latter are important determinants of private expenditure (e.g. opportunity cost), then the net effect of reserve requirements on aggregate demand is uncertain ( $x_z \leq 0$ ).

Second, reserve requirements are distortionary taxes on financial intermediation (Reinhart and Reinhart (1999)). As such, they are costly for society and their desirable level must be related to

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<sup>3</sup>Nevertheless, the authors specified neither the magnitude of the reserve requirements movement nor whether it was equal for all countries.

their costs relative to those of other distortionary taxes. Reserve requirements may also alleviate bank liquidity risk. For all these reasons, it may be argued that there exists an optimal, long term level for reserve requirements ( $\hat{z}$ ). Deviations from this level are socially costly. Hence, when assessing the use of reserve requirements as a monetary policy tool, the CB considers the cost of moving away from their optimal long term level, which may be represented as  $\frac{\rho}{2}(z - \hat{z})^2$ .

With these two considerations, the IT model extended to include reserve requirements posits a CB that finds the values of  $i$  and  $z$  that solve the following problem

$$\min_{i,z} \frac{\pi^2}{2} + \frac{\lambda x^2}{2} + \frac{\rho(z - \hat{z})^2}{2}, \quad (1)$$

Subject to a Phillips curve (2) and an IS curve (3) <sup>4</sup>:

$$\pi = \pi^e + \alpha x + \xi \quad (2)$$

$$x = x(i, z) + u. \quad (3)$$

The CB loss function assumes a zero inflation target. The Phillips curve relates inflation ( $\pi$ ) to inflation expectations ( $\pi^e$ ), the output gap ( $x$ ) and a supply shock ( $\xi$ ). The first order necessary conditions for this problem are as follows:

$$\begin{aligned} (\alpha\pi + \lambda x)x_i &= 0 \\ (\alpha\pi + \lambda x)x_z + \rho(z - \hat{z}) &= 0, \end{aligned}$$

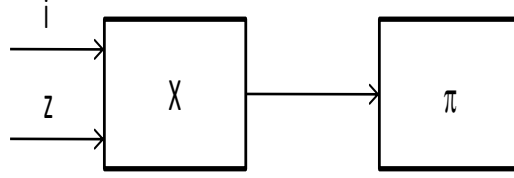
where  $x_i$  and  $x_z$  represent the partial derivatives of the output gap with respect to the policy interest rate and reserve requirements, respectively.

These conditions imply that the CB must set  $i$  so that  $\alpha\pi + \lambda x = 0$  and  $z = \hat{z}$ . In other words, the CB must always set  $z$  at its optimal long term value and adjust  $i$  to reach the value that best solves the trade-off between inflation and the output gap. The intuition behind this result is simple: since  $i$  and  $z$  work through the same transmission channel (moving  $x$  and thereby  $\pi$ ), the use of reserve requirements does not improve the trade-off between inflation and output, but it implies social costs if they deviate from their long term optimal value. Hence, the best CB policy minimizes the direct cost of reserve requirements deviations and uses the policy interest rate to optimize the trade-off between inflation and output.

In sum, reserve requirements play no role as a monetary policy tool when the CB has three objectives ( $\pi, x, z$ ) and one transmission channel ( $x$  in Figure 1), because the CB finds the value of  $x$  that minimizes its loss function ( $x^*$ ) and then adjusts  $i$  and  $z$  to reach it at the minimum cost:  $z^* = \hat{z}$  and  $i^*$  such that  $x^* = x(i^*, \hat{z})$ .

<sup>4</sup>The IS curve presented in equation (3) may be derived from a conventional IS curve  $x = f(i_l - \bar{i}_l, i_d - \bar{i}_d)$ , where  $i_l$  and  $i_d$  are the lending and deposit interest rates, respectively (Bernanke and Blinder (1988)). The equilibrium values of these interest rates stem from the equilibrium conditions in the loan and deposit markets, in which the deposit demand and loan supply by banks depend on the policy rate and reserve requirements.

FIGURE 1



This result holds regardless of the power of the transmission mechanism from  $i$  to  $x$  and  $\pi$ , or from  $z$  to  $x$  and  $\pi$ . Thus, if the transmission from the interest rate to aggregate demand and inflation is weakened, optimal policy prescribes a stronger adjustment of  $i$  and constant reserve requirements at  $z^* = \hat{z}$ . From the point of view of optimal monetary policy, a weaker transmission channel from the policy interest rate to aggregate expenditure does not justify the use of reserve requirements as a monetary policy instrument. However, these results may change if the model is generalized to include more transmission channels of monetary policy or more CB objectives.

**3.2. An open economy model (model II).** Now we consider a model similar to the previous one, but in an open economy. The CB has the same three objectives  $(\pi, x, z)$ , but there is an additional transmission channel associated with the exchange rate. In this case, the CB minimizes the same loss function (1), subject to open economy Phillips (4) and IS (5) curves, and to a relationship between nominal depreciation ( $s$ ), the interest rate, reserve requirements and external shocks to the exchange rate (6):

$$\pi = \pi^e + \alpha x + Bs + \xi \quad (4)$$

$$x = x(i, z, s) + u \quad (5)$$

$$s = s(i, z) + v. \quad (6)$$

In this model the nominal depreciation affects inflation directly in the Phillips curve and indirectly through the IS curve. This is a new channel through which changes in  $i$  or  $z$  may affect  $\pi$  or  $x$ . Movements in the policy interest rate or in reserve requirements shift lending and deposit interest rates and so the exchange rate (the nominal depreciation), as capital flows adjust the parity conditions of domestic and external interest rates. The first order necessary conditions for the CB optimization problem in an open economy are as follow:

$$\pi(\alpha(x_i + x_s s_i) + B s_i) + \lambda x(x_i + x_s s_i) = 0 \quad (7)$$

$$\pi(\alpha(x_z + x_s s_z) + B s_z) + \lambda x(x_z + x_s s_z) + \rho(z - \hat{z}) = 0. \quad (8)$$

These conditions may be stated as:

$$(\alpha\pi + \lambda x)(x_i + x_s s_i) = -\pi B s_i \quad (9)$$

$$(\alpha\pi + \lambda x)(x_z + x_s s_z) + \rho(z - \hat{z}) = -\pi B s_z. \quad (10)$$

Substituting equation (9) into (10) yields:

$$z = \hat{z} + \frac{B\pi}{\rho} \left[ \frac{x_z s_i - x_i s_z}{x_i + x_s s_i} \right]. \quad (11)$$

Reserve requirements play a relevant role in an optimal monetary policy setting ( $z \neq \hat{z}$ ) if: i) inflation is off target (away from zero in this model), ii) there is a pass-through from the exchange rate to local prices ( $B \neq 0$ ) and iii) the ratio between the effects of the policy interest rate and the reserve requirements on the exchange rates differs from the ratio of the effects that these instruments have on aggregate demand ( $s_i/s_z \neq x_i/x_z$ ). Moreover, equation (11) implies that the magnitude of the use of reserve requirements is inversely related to the weight of their deviations in the CB loss function,  $\rho$ .

According to equation (11), to understand the role of reserve requirements in this context, it is necessary to determine the signs of the derivatives  $x_i, s_i, x_z, s_z$  y  $x_s$ . In general, increases in the policy interest rates raise bank lending and deposit interest rates, thereby reducing aggregate demand due to substitution effects and higher opportunity costs ( $x_i < 0$ ). Similarly, ceteris paribus, it induces capital inflows that appreciate the currency ( $s_i < 0$ ).

In contrast, an increase in reserve requirements has an ambiguous effect both on the output gap ( $x$ ) and on the exchange rate ( $s$ ). If higher reserve requirements raise lending rates and decrease deposit rates, their impact on aggregate expenditure is uncertain. It depends on the relevance of each of those interest rates in the private sector spending decisions. We will assume henceforth that  $x_z < 0$ , either because lending rates are more important than deposit rates as determinants of private demand, or because reserve requirements increase deposit interest rates (a result theoretically feasible according to Betancourt and Vargas (2009) and empirically observed in some cases, e.g. Vargas et al. (2010)).

Also, based on the previous arguments, the effect of reserve requirements on currency depreciation is uncertain. If deposit interest rates are the main determinant of capital flows and if an increase in reserve requirements reduces those rates, then  $s_z > 0$ . By decreasing deposit interest rates, capital flows out of the country and the currency depreciates. In contrast, if reserve requirements raise deposit interest rates or if lending rates are the main determinants of capital flows, then  $s_z < 0$ . Finally, we assume that, ceteris paribus, a depreciation has an expansionary effect on output in the short term,  $x_s > 0$ . In sum, we make the following assumptions on the relevant derivatives:  $x_i < 0, s_i < 0, x_z < 0, s_z \leq 0$ , y  $x_s > 0$ .

To better understand the situations in which equilibrium inflation deviates from its target and reserve requirements are part of an optimal monetary policy, it is useful to examine the response of the CB to different shocks hitting the economy. With this aim, we apply comparative statics to the first order conditions (7) and (8), assuming that the slopes  $x_s, x_i, x_z, s_i, s_z$  are constant. Defining  $A \equiv x_i + x_s s_i$  ( $A < 0$ ) and  $D \equiv x_z + x_s s_z$ , the equations (7) and (8) may be written as:

$$\pi(\alpha A + B s_i) + \lambda x A = 0 \quad (12)$$

$$\pi(\alpha D + B s_z) + \lambda x D + \rho(z - \hat{z}) = 0. \quad (13)$$

Taking into account equations (4), (5) and (6), we totally differentiate first order conditions (12) and (13) to get:



$$\begin{aligned}
& (\alpha A + Bs_i)(d\pi^e + d\xi + B(s_i d_i + s_z d_z + dv) + \alpha(x_i d_i + x_z d_z + x_s(s_i d_i + s_z d_z + dv) + du)) \\
& + \lambda A(x_i d_i + x_z d_z + x_s(s_i d_i + s_z d_z + dv) + du) = 0
\end{aligned} \tag{14}$$

$$\begin{aligned}
& (\alpha D + Bs_i)(d\pi^e + d\xi + B(s_i d_i + s_z d_z + dv) + \alpha(x_i d_i + x_z d_z + x_s(s_i d_i + s_z d_z + dv) + du)) \\
& + \lambda D(x_i d_i + x_z d_z + x_s(s_i d_i + s_z d_z + dv) + du) + \rho dz = 0.
\end{aligned} \tag{15}$$

The comparative statics results are explained below.

#### Demand Shocks:

$$\frac{di}{du} = -\frac{\alpha B \rho s_i + \alpha^2 \rho A + \lambda(\rho A + B^2 s_z (s_z x_i - s_i x_z))}{2\alpha B \rho s_i A + (\alpha^2 + \lambda)\rho A^2 + B^2(\rho^2 s_i^2 + \lambda(s_z x_i - s_i x_z)^2)} \tag{16}$$

$$\frac{dz}{du} = \frac{B^2 \lambda s_i (s_z x_i - s_i x_z)}{F}, \tag{17}$$

where  $F > 0$  is the denominator of equation (16). When  $B = 0$  (there is no direct pass-through in the Phillips curve), the second transmission channel disappears and, according to the results of the previous section, reserve requirements play no active role in the optimal monetary policy response to a demand shock. In this case, the foregoing equations are reduced to:

$$\frac{di}{du} = -\frac{1}{A} > 0 \tag{18}$$

$$\frac{dz}{du} = 0. \tag{19}$$

Reserve requirements are optimally used to react to a demand shock only if  $B \neq 0$  and  $s_z x_i - s_i x_z \neq 0$ . The direction of the response of reserve requirements depends on two factors: i) their impact on the exchange rate ( $s_z$ ) and ii) the difference between the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate, and the ratio of the effects of these two instruments on aggregate demand.

When an increase in reserve requirements depreciates the currency ( $s_z > 0$ ), the CB will choose to raise both reserve requirements and interest rates in the face of a positive demand shock. Intuitively, to fully compensate the demand shock, the CB must increase the policy interest rate in a magnitude such that a currency appreciation is produced and an undesired reduction in inflation results (below the inflation target). Therefore, the adjustment of the interest rate cannot be the one required to bring the output gap to zero. Thus, the trade-off between  $x$  and  $\pi$  implies  $x > 0$  and  $\pi < 0$  when only the interest rate is used. In this situation, an increase in reserve requirements improves the trade-off facing the CB, because it contributes simultaneously to reduce  $x$ , bringing it close to zero ( $x_z < 0$ ), and to increase  $\pi$ , bringing it close to zero too ( $s_z > 0$ ). Hence, in this case reserve requirements work as a complement of the policy interest rate.

When a rise of reserve requirements appreciates the currency ( $s_z < 0$ ), their benefits as a monetary policy tool are lower because their impact on the exchange rate and inflation goes in the same direction as that of the interest rate. More specifically, the response of reserve requirements to the demand shock depends on the difference between the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate, and the ratio of the effects of these two instruments on aggregate demand. If  $s_i/s_z > x_i/x_z$ , then reserve requirements are attractive with respect to the interest rate to offset the demand shock because they moderate aggregate expenditure with an impact on inflation that is lower than the one that is produced when the interest rate is used. In this case, the CB employs reserve requirements as a substitute of interest rates<sup>5</sup>. However, this substitution is not complete due to the costs of the distortions that reserve requirements introduce.

On the other hand, if  $s_z < 0$  and  $s_i/s_z < x_i/x_z$ , the optimal response of the CB to the positive demand shock involves a reduction in reserve requirements and an increase of the interest rate. In this case, the decrease in reserve requirements moderates the fall of inflation (through a depreciation of the currency), without strongly offsetting the impact of the interest rate increase on the output gap.

Supply Shocks:

$$\frac{di}{d\xi} = -\frac{\alpha\rho A + B(\rho s_i - \lambda D(s_z x_i - s_i x_z))}{F} \quad (20)$$

$$\frac{dz}{d\xi} = -\frac{B\lambda A(s_z x_i - s_i x_z)}{F}. \quad (21)$$

Again, if  $B = 0$  (no pass-through), then

$$\frac{di}{d\xi} = -\frac{\alpha}{(\alpha^2 + \lambda)A} > 0 \quad (22)$$

$$\frac{dz}{d\xi} = 0. \quad (23)$$

As in the case of a demand shock, the optimal policy response to a supply shock includes an adjustment of reserve requirements if there exists pass-through from the exchange rate to local prices in the Phillips curve ( $B > 0$  in equation (21)) and if the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate differs from the ratio of the effects of these two instruments on aggregate demand ( $s_z x_i - s_i x_z \neq 0$  in equation (21)). The direction of the response of reserve requirements depends, as in the case of the demand shock, on their impact on the exchange rate ( $s_z$ ) and on the difference between the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate, and the ratio of the effects of these two instruments on aggregate demand.

When an increase in reserve requirements depreciates the currency ( $s_z > 0$ ), the CB will choose to raise the interest rate<sup>6</sup> and to reduce reserve requirements in the face of a supply shock. Intuitively, the CB raises the interest rate to contain the increase in inflation at the expense of a sacrifice in

<sup>5</sup>If  $s_z < 0$ , it is necessary that  $|\alpha B s_i + \alpha^2 \rho A + \lambda \rho A| > \lambda B^2 s_z (s_z x_i - s_i x_z)$  for the interest rate to increase as a response to the demand shock.

<sup>6</sup>If  $s_z > 0$ , for  $\frac{di}{d\xi} > 0$  we need  $|x_z| > x_s s_z$  (which implies  $D < 0$ ) or if  $|\rho s_i| < |\lambda D (s_z x_i - s_i x_z)|$  then  $|\alpha \rho A| > B(\rho s_i - \lambda D (s_z x_i - s_i x_z))$ .

the output gap. This trade-off is improved if the CB decreases reserve requirements to encourage private spending ( $x_z < 0$ ), while reducing inflation at the same time through an appreciation of the currency (the fall of reserve requirements pushes deposit interest rates up,  $s_z > 0$ ).

When a rise of reserve requirements appreciates the currency ( $s_z < 0$ ), the optimal monetary policy response involves an increase in interest rates<sup>7</sup> and a movement in reserve requirements that depends on the difference between the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate, and the ratio of the effects of these two instruments on aggregate demand. Specifically, if  $s_i/s_z < x_i/x_z$ , the CB ups reserve requirements to reduce inflation with an output sacrifice that is lower than the one resulting if the interest rate is used. In this case, reserve requirements act as a substitute of the interest rate. On the other hand, if  $s_i/s_z > x_i/x_z$ , the CB reduces reserve requirements to moderate the fall in output with a relatively small rise in inflation.

Inflation Expectations Shocks: The analysis is the same as the one for the supply shock given that:

$$\frac{di}{d\pi^e} = \frac{di}{d\xi} \quad (24)$$

$$\frac{dz}{d\pi^e} = \frac{dz}{d\xi}. \quad (25)$$

Depreciation Shocks:

$$\frac{di}{dv} = \frac{-((\alpha^2 + \lambda)\rho x_s A) + \alpha B \rho (x_i + 2s_i x_s) + B^2(\rho s_i + \lambda x_z (s_i x_z - s_z x_i))}{F} \quad (26)$$

$$\frac{dz}{dv} = \frac{B^2 \lambda x_i (s_i x_z - s_z x_i)}{F}. \quad (27)$$

If there is no pass-through ( $B = 0$ ):

$$\frac{di}{dv} = \frac{-x_s}{A} \quad (28)$$

$$\frac{dz}{dv} = 0. \quad (29)$$

A depreciation shock has impacts similar to those resulting from the supply shock. That is, it pushes inflation up and requires an increase in the interest rate to moderate the rise in inflation with a sacrifice in terms of the output gap. As in the case of the supply shock, the optimal monetary policy response involves an adjustment in reserve requirements if there is a pass-through effect in the Phillips curve ( $B > 0$  in equation (27)) and if the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate differs from the ratio of the effects of these two instruments on aggregate demand ( $s_z x_i - s_i x_z \neq 0$  in equation (27)). Also, as in the case of the supply shock, the direction of the movements of reserve requirements depends on their impact on the exchange rate ( $s_z$ ) and on the difference between the ratio of the effects of the policy

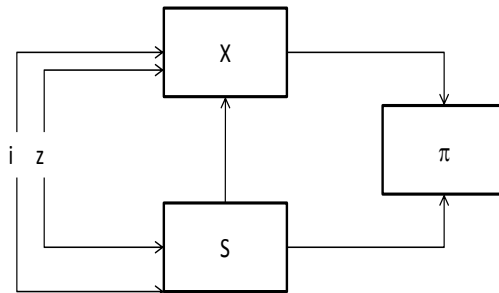
<sup>7</sup>If  $s_z < 0$ , for  $\frac{di}{d\xi} > 0$  it suffices that  $s_z x_i < s_i x_z$ . If  $s_z x_i > s_i x_z$  then we need  $|\rho s_i| > |\lambda D(s_z x_i - s_i x_z)|$  or if  $|\rho s_i| < |\lambda D(s_z x_i - s_i x_z)|$  then it is required that  $|\alpha \rho A| > B(\rho s_i - \lambda D(s_z x_i - s_i x_z))$ .

interest rate and reserve requirements on the exchange rate, and the ratio of the effects of these two instruments on aggregate demand. The intuition of this result is the same as the one provided for the supply shock.

Of particular interest are those situations in which reserve requirements and the policy interest rate are adjusted in opposite directions in response to an exchange rate shock. This happens more clearly when a rise of reserve requirements depreciates the currency ( $s_z > 0$ ). In this circumstances, for example, an appreciation shock requires a reduction of interest rates and an increase of reserve requirements. The decrease in interest rates moderates the fall of inflation, but produces a positive output gap. The rise of reserve requirements simultaneously moderates the increase of the output gap and the fall of inflation. Even if there is a negative relationship between reserve requirements and the exchange rate ( $s_z < 0$ ), the optimal response to an appreciation shock involves a reduction of interest rates and an upward movement of reserve requirements when  $s_i/s_z > x_i/x_z$ . In this case, higher reserve requirements moderate the output gap at the expense of relatively small reduction of inflation, which makes the CB better off.

In brief, unlike their passive role in the simple, closed economy model presented in the previous section, theoretically reserve requirements are part of the optimal monetary policy response to different shocks hitting an open economy with a pass-through effect in the Phillips curve. This occurs because in the presence of three CB objectives ( $\pi, x, z$ ) and two transmission channels ( $x$  and  $s$  in Figure 2), a shock that moves inflation or output away from their optimal levels may induce changes in the interest rates that affect inflation independently from the output gap, by the pass-through effect in the Phillips curve ( $B \neq 0$ ). In this situation, reserve requirements may improve the CB trade-off between inflation and output, as long as the ratio of the effects of the policy interest rate and reserve requirements on the exchange rate differs from the ratio of the effects of these two instruments on aggregate demand, and, especially, if reserve requirements impact the depreciation of the currency and the output gap in opposite directions. In particular, if  $s_z > 0$ , the role of reserve requirements in the monetary policy reaction will be generally more important. As with the response of the policy interest rate, the optimal adjustment of reserve requirements differs depending on the type of shock affecting the economy.

FIGURE 2



#### 4. IN WHICH OTHER SITUATIONS ARE RESERVE REQUIREMENTS USEFUL AS A MONETARY POLICY TOOL?

When the CB has three objectives  $(\pi, x, z)$  and one transmission channel  $(x)$ , reserve requirements play no active role in the optimal monetary policy response to a shock hitting the economy. In the case of three objectives  $(\pi, x, z)$  and two transmission channels  $(x, s)$ , reserve requirements may be part of the optimal monetary policy reaction and their use depends on the parameters of the economy and on the shocks that it faces. Another case in which reserve requirements may be included in an optimal monetary policy decision occurs when the CB has an additional objective, for example, financial stability. In this situation, reserve requirements can improve the trade-offs confronted by the CB.

According to Disyatat (2010), incorporating financial stability considerations in monetary policy models entails difficulties that justify the operational inclusion of a financial imbalance measure in the CB loss function. The point is that it is presumably easier to find the connection between policy actions and financial imbalance measures than to assess the link between those actions and the probability of financial crises in the distant future. Disyatat (2010) argues that the financial stability component of the CB loss function should be asymmetric. For simplicity we use a symmetric quadratic loss function, but we interpret the results of the model in the cases in which shocks may induce excessive leverage. Namely, the CB problem becomes:

$$\min_{i,z} \frac{\pi^2}{2} + \frac{\lambda x^2}{2} + \frac{\gamma c^2}{2} + \frac{\rho(z - \hat{z})^2}{2}, \quad (30)$$

subject to a closed economy Phillips curve, the relationship between market interest rates (lending and deposit) and the policy interest rate and reserve requirements, the IS curve and a measure of excessive leverage ( $c$ ):

$$\pi = \pi^e + \alpha x + \xi \quad (31)$$

$$i_d = i^d(i, z) \quad (32)$$

$$i_l = i^l(i, z) + \varepsilon \quad (33)$$

$$x = x(i_d, i_l) + u \quad (34)$$

$$c = c_y x + c_l i_l. \quad (35)$$

Equation (35) represents a credit demand function<sup>8</sup> with  $c_y > 0$  and  $c_l < 0$  as coefficients. Notice that by including the shock  $\varepsilon$  in the lending interest rate equation  $i_l$  and not in the credit demand equation, we are implicitly interpreting it as credit supply shock. The first order necessary conditions for this problem imply that:

<sup>8</sup> $c$  may be understood as a deviation from credit demand from its steady state value:  $C = (\bar{Y} + x, i_l) - C(\bar{Y}, \bar{i}_l)$ , where  $\bar{Y}$  and  $\bar{i}_l$  represent the steady state values of income and the lending interest rate, respectively.

$$z = \hat{z} + \frac{\gamma c c_l}{\rho} \left[ \frac{x_{id}(i_z^d i_i^l - i_i^d i_z^l)}{x_{id} i_i^d + x_{il} i_i^l} \right]. \quad (36)$$

Optimal monetary policy involves the use of reserve requirements as a tool ( $z \neq \hat{z}$ ) if: i) excess leverage is different from zero ( $c \neq 0$ ), ii) the CB cares about financial stability ( $\gamma > 0$ ) and iii) the ratio between the effects of the policy interest rate and reserve requirements on the lending interest rate differs from the ratio between the effects of these two instruments on the deposit rate ( $i_i^l/i_z^l \neq i_i^d/i_z^d$ ). Further, the magnitude of the reserve requirement adjustment is directly related to the weight of financial stability in the CB loss function,  $\gamma$ , and inversely related to the weight of reserve requirements deviations from its optimal long term level in the loss function,  $\rho$ .

According to equation (36), to better understand the role of reserve requirements in this context, it is necessary to assess the signs of the derivatives  $x_{id}, x_{il}, i_i^d, i_i^l, i_z^l$  and  $i_z^d$ . Normally, increases in the policy interest rate raise lending and deposit interest rates ( $i_i^l > 0, i_i^d > 0$ ), and reduce aggregate demand through substitution effects and larger opportunity costs ( $x_{il} < 0, x_{id} < 0$ ). With respect to reserve requirements, we assume that bank deposits and open market operations of the CB are not perfect substitutes as sources of bank funding. Therefore, an increase in reserve requirements induces higher lending interest rates ( $i_z^l > 0$ ) and has an ambiguous effect on lending interest rates ( $i_z^d \leq 0$ ) (Betancourt and Vargas (2009)).

To examine the monetary policy response to different shocks we applied comparative statics on the first order conditions, assuming constant slopes. We focus on the shocks that generate the risk of financial stability, defined as  $c > 0$ . The case  $c < 0$  is not relevant from the point of view of financial imbalances.

Negative Demand Shocks ( $du < 0$ ): We consider events that impact aggregate demand without affecting credit supply at the same time. E.g. sharp falls in public or external demand that do not influence directly the credit market (unlike shocks to expectations, confidence or risk aversion). The optimal responses of the interest rate and reserve requirements to this shock are the following:

$$\frac{di}{du} = \frac{-c_l c_y \gamma i_i^l \rho + c_l^2 \gamma i_z^l x_{id} (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l) - \rho J (\alpha^2 + c_y^2 \gamma + \lambda)}{c_l^2 \gamma ((i_i^l)^2 \rho + (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l)^2 x_{id}^2) + 2c_l c_y \gamma i_i^l \rho J + \rho J^2 (\alpha^2 + c_y^2 \gamma + \lambda)} \quad (37)$$

$$\frac{dz}{du} = \frac{-c_l^2 \gamma i_i^l x_{id} (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l)}{K}, \quad (38)$$

where  $J = (i_i^d x_{id} + i_i^l x_{il})$  and  $K$  is the denominator of the right hand side of equation (37)<sup>9</sup>. The direction of the reserve requirements response depends on their impact on deposit interest rates and the difference between the ratio of the effects of the policy interest rate and reserve requirements on the lending interest rate and the ratio of the effects of these two instruments on the deposit rate.

When there is an inverse relationship between reserve requirements and deposit interest rates ( $i_z^d < 0$ ), the CB decreases interest rates and raises reserve requirements at the same time in the face of a negative demand shock. Intuitively, to offset the demand shock, the CB would have to lower the interest rate to such an extent that it would generate excess leverage. Hence, the optimal

<sup>9</sup> $J < 0; K > 0$ .

adjustment of the interest rate cannot be enough to bring the output gap and inflation to zero. Thus, the trade-off between  $x$ ,  $\pi$  y  $c$  implies  $x < 0$ ,  $\pi < 0$  and  $c > 0$  when only the interest rate is used. In this situation, a rise in reserve requirements improves the CB trade-off, because it simultaneously increases  $x$  (through lower deposit interest rates) and reduces  $c$  (through higher lending interest rates). Therefore, in this case both instruments are complements.

When there is a direct relationship between reserve requirements and deposit interest rates ( $i_z^d > 0$ ), the benefits of reserve requirements as a policy tool are lower because their effects on lending and deposit interest rates go in the same direction as those of the policy rate. The response of reserve requirements to the negative demand shock depends on the difference between the ratio of the effects of the policy interest rate and reserve requirements on the lending interest rate and the ratio of the effects of these two instruments on the deposit rate. If  $i_z^d > 0$  and  $i_i^l/i_z^l < i_i^d/i_z^d$ , the optimal monetary policy reaction involves an increase in reserve requirements and a reduction of the policy interest rate. Here higher reserve requirements moderate leverage (through a higher lending interest rate) with only a small offsetting effect on the impulse provided by the fall of the policy rate.

In contrast, if  $i_i^l/i_z^l > i_i^d/i_z^d$ , the optimal response to the shock includes a reduction of both the policy interest rate<sup>10</sup> and reserve requirements. In this case, the latter are attractive with respect to the interest rate to confront the demand shock because they encourage aggregate expenditure with an effect on credit supply that is lower than the one resulting from the use of the interest rate. This induces the CB to employ reserve requirements as a substitute instrument of the interest rate. Nonetheless, there is no complete substitution due to the distortionary cost introduced by reserve requirements.

Positive Supply Shocks ( $d\xi < 0$ ): This shock drives inflation below target. Then, the optimal policy reaction is to reduce the interest rate<sup>11</sup> and tolerate a period in which output is above its potential level. This higher income and the lower interest rates might generate excessive leverage. In this context reserve requirements can alleviate the CB trade-off. The optimal responses of the interest rate and reserve requirements to this shock are the following:

$$\frac{di}{d\xi} = \frac{\alpha(c_l \gamma x_{i_d}(i_z^d i_i^l - i_i^d i_z^l)(c_l i_z^l + c_y(i_z^d x_{i_d} - i_z^l x_{i_l})) - \rho J)}{K} \quad (39)$$

$$\frac{dz}{d\xi} = \frac{-(\alpha c_l \gamma x_{i_d}(i_z^d i_i^l - i_i^d i_z^l)(c_l i_i^l + c_y i_i^d x_{i_d} + c_y i_i^l x_{i_l}))}{K}. \quad (40)$$

The direction of the reserve requirements response depends on their impact on deposit interest rates ( $i_z^d$ ) and the difference between the ratio of the effects of the policy interest rate and reserve requirements on the lending interest rate and the ratio of the effects of these two instruments on the deposit rate.

<sup>10</sup>It is required that  $-c_l c_y \gamma i_i^l \rho - \rho J(\alpha^2 + c_y^2 \gamma + \lambda) > |c_l^2 \gamma i_z^l x_{i_d}(\alpha^2 + \lambda)(i_z^d i_i^l - i_i^d i_z^l)|$ .

<sup>11</sup>For  $\frac{di}{d\xi} > 0$  if  $i_z^d < 0$  it suffices that  $|c_l i_z^l| > c_y(i_z^d x_{i_d} - i_z^l x_{i_l})$ . Alternatively, if  $i_z^d < 0$  and  $|c_l i_z^l| < c_y(i_z^d x_{i_d} - i_z^l x_{i_l})$ , then it suffices that  $|\rho J| > c_l \gamma x_{i_d}(i_z^d i_i^l - i_i^d i_z^l)(c_l i_z^l + c_y(i_z^d x_{i_d} - i_z^l x_{i_l}))$ . If  $i_z^d > 0$ ,  $i_z^d i_i^l < i_i^d i_z^l$  and  $|i_z^d x_{i_d}| < |i_z^l x_{i_l}|$ , the same conditions as in the case of  $i_z^d < 0$  are sufficient. If  $i_z^d > 0$ ,  $i_z^d i_i^l > i_i^d i_z^l$  and  $|i_z^d x_{i_d}| < |i_z^l x_{i_l}|$  we need  $|c_l i_z^l| < c_y(i_z^d x_{i_d} - i_z^l x_{i_l})$ . If  $i_z^d > 0$ ,  $i_z^d i_i^l > i_i^d i_z^l$  and  $|i_z^d x_{i_d}| > |i_z^l x_{i_l}|$  then we need that  $|\rho J| > |c_l \gamma x_{i_d}(i_z^d i_i^l - i_i^d i_z^l)(c_l i_z^l + c_y(i_z^d x_{i_d} - i_z^l x_{i_l}))|$ .

When a rise in reserve requirements lowers the lending interest rate ( $i_z^d < 0$ ), the CB increases reserve requirements and reduces the interest rate when facing a positive supply shock. Intuitively, to offset the shock, the CB would have to lower the interest rate to such an extent that it would generate excess leverage and a positive output gap. Hence, the optimal adjustment of the interest rate cannot be enough to bring inflation to zero. Thus, the trade-off between  $x$ ,  $\pi$  and  $c$  implies  $x > 0$ ,  $\pi < 0$  and  $c > 0$  when only the interest rate is used. In this situation, a rise in reserve requirements increases the lending interest rate, thereby reducing leverage and the output gap. The last effect produces an undesired fall in inflation, which is compensated by the lower deposit interest rates stemming from higher reserve requirements.

When there is a positive relationship between reserve requirements and the deposit interest rate ( $i_z^d > 0$ ), the benefits of reserve requirements are lower because their effect on lending and deposit rates go in the same direction as those resulting from shifts in the policy interest rate. The response of reserve requirements to the positive supply shock depends on the difference between the ratio of the effects of the policy interest rate and reserve requirements on the lending interest rate and the ratio of the effects of these two instruments on the deposit rate. If  $i_z^d > 0$  and  $i_i^l/i_z^l < i_i^d/i_z^d$ , the optimal monetary policy reaction involves an increase in reserve requirements and a reduction of the policy interest rate. Recall that the positive supply shock and the decrease in the policy interest rate drive inflation below its target ( $\pi < 0$ ) and output and credit above their optimal values ( $x > 0$  and  $c > 0$ ). In these circumstances, a rise in reserve requirements lowers the output gap and credit (through an increase in lending rates) and brings these variables close to their optimal values. However, this movement reduces inflation at the same time, driving it away from its target. When  $i_i^l/i_z^l < i_i^d/i_z^d$ , the impact of reserve requirements on lending rates is relatively strong and the net benefit of raising them is positive, since the gains from curbing excess leverage and expenditure outweighs the cost of a lower inflation rate.

In contrast, if  $i_i^l/i_z^l > i_i^d/i_z^d$ , the optimal response to the shock includes a decrease in both reserve requirements and the policy interest rate. Here, reserve requirements are attractive with respect to the interest rate to face the shock because they encourage aggregate expenditure and inflation, with an impact on credit supply that is lower than the one resulting from the use of the policy interest rate. Thus, the CB views reserve requirements as a substitute for the interest rate in this case. As before, the substitution is not complete due to the distortionary costs of reserve requirements.

Positive Credit Supply Shocks ( $d\epsilon < 0$ ): This is a shock that diminishes the lending interest rate offered by credit suppliers. A positive shock (related to lower risk aversion or a reassessment of credit versus market risk in banks portfolios), not only generates excessive leverage, but also an increase in the output gap and inflation (through a lower lending interest rate). The optimal monetary policy reaction typically involves higher policy interest rates<sup>12</sup> to contain indebtedness and excessive expenditure. However, depending on the parameters of the economy, reserve requirements may improve the CB trade-off. The first order conditions imply the following policy rate and reserve requirement responses to the positive credit supply shock:

$$\frac{di}{d\epsilon} = - \frac{c_l^2 \gamma (i_i^l \rho + i_z^d x_{i_d}^2 (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l)) + \rho x_{i_i} J (\alpha^2 + c_y^2 \gamma + \lambda) + c_l c_y \gamma \rho (i_i^d x_{i_d} + 2 i_i^l x_{i_i})}{K} \quad (41)$$

<sup>12</sup>For  $\frac{di}{d\epsilon} < 0$  if  $i_z^d > 0$  it suffices that  $i_z^d i_i^l > i_i^d i_z^l$ . If  $i_z^d i_i^l < i_i^d i_z^l$  we need that  $i_i^l \rho > |i_z^d x_{i_d}^2 (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l)|$  or if  $i_i^l \rho < |i_z^d x_{i_d}^2 (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l)|$  then  $\rho x_{i_i} J (\alpha^2 + c_y^2 \gamma + \lambda) + c_l c_y \gamma \rho (i_i^d x_{i_d} + 2 i_i^l x_{i_i}) > |c_l^2 \gamma (i_i^l \rho + i_z^d x_{i_d}^2 (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l))|$ .



$$\frac{dz}{d\varepsilon} = \frac{c^2 i_i^d \gamma x_{i_d}^2 (\alpha^2 + \lambda) (i_z^d i_i^l - i_i^d i_z^l)}{K}. \quad (42)$$

The direction of the reserve requirements response depends on their impact on deposit interest rates ( $i_z^d$ ) and the difference between the ratio of the effects of the policy interest rate and reserve requirements on the lending interest rate and the ratio of the effects of these two instruments on the deposit rate.

When an upward movement of reserve requirements reduces deposit interest rates ( $i_z^d < 0$ ), the CB increases both the policy interest rate and the reserve requirements. Intuitively, to offset the shock, the CB would have to raise the interest rate to such an extent that it would drive the output gap and inflation below their targets. Hence, the optimal adjustment in the interest rate cannot be as large and the trade-off between  $x$ ,  $\pi$  and  $c$  implies  $x < 0$ ,  $\pi < 0$  and  $c > 0$  when only the interest rate is used. In this situation, a rise in reserve requirements increases the lending interest rate, containing leverage, but further reducing the output gap and inflation. However, the last effect is compensated by a fall of the deposit interest rate stemming from higher reserve requirements.

When there is a positive relationship between reserve requirements and the deposit interest rate ( $i_z^d > 0$ ), the benefits of reserve requirements are lower because their effect on lending and deposit rates go in the same direction as those resulting from shifts in the policy interest rate. The response of reserve requirements to the positive credit supply shock depends on the difference between the ratio of the effects of the policy interest rate and reserve requirements on the lending interest rate and the ratio of the effects of these two instruments on the deposit rate. If  $i_z^d > 0$  and  $i_i^l/i_z^l < i_i^d/i_z^d$ , the optimal monetary policy reaction involves an increase of both reserve requirements and the policy interest rate. In this case, reserve requirements are attractive with respect to the interest rate to face the shock because they have a strong impact on lending rates and leverage. Thus, the CB views reserve requirements as a substitute for the interest rate. As before, the substitution is not complete due to the distortionary costs of reserve requirements.

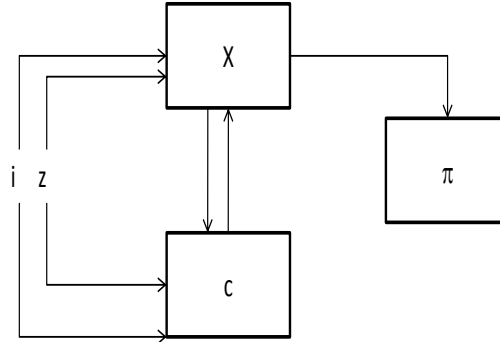
In contrast, if  $i_i^l/i_z^l > i_i^d/i_z^d$ , the optimal response to the shock involves a reduction in reserve requirements and an increase in the policy rate. The latter is now a powerful instrument to curb leverage relative to reserve requirements. Hence, the CB tries to correct excessive leverage with the interest rate and moderates the collateral effect on output and inflation by means of a decrease in reserve requirements.

In sum, reserve requirements may play a role as part of optimal monetary policy when the CB has four objectives ( $\pi, x, z, c$ ) and two transmission channels ( $x$  and  $c$  in Figure 3). If only the interest rate is used to respond to macroeconomic shocks, it is possible that excessive leverage emerge. In this situation, reserve requirements may improve the CB trade-offs. In particular, the use of reserve requirements may be desirable when they have strong effects on leverage.

## 5. AN APPLICATION: COLOMBIA

The foregoing results indicate that the relevance, magnitude and direction of shifts in reserve requirements as part of optimal monetary policy depend on the existence of several transmission

FIGURE 3



channels, the CB objectives, the parameters of the economy and the type of shocks that affect it<sup>13</sup>. In general, the use of reserve requirements seems to be advantageous when they have opposite effects on lending and deposit interest rates. In this case, their impact differs from the policy rate's and, hence, their contribution to a better macroeconomic adjustment is higher.

For Colombia, Vargas et al. (2010) find a positive long term relationship between reserve requirements and long term CD rates, while no statistically significant relationship is found between reserve requirements and the interest rates of other types of deposits. Also, there seems to be a direct relationship between reserve requirements and some lending interest rates. Therefore, the case in which reserve requirements are more valuable as part of optimal monetary policy does not appear to hold in Colombia.

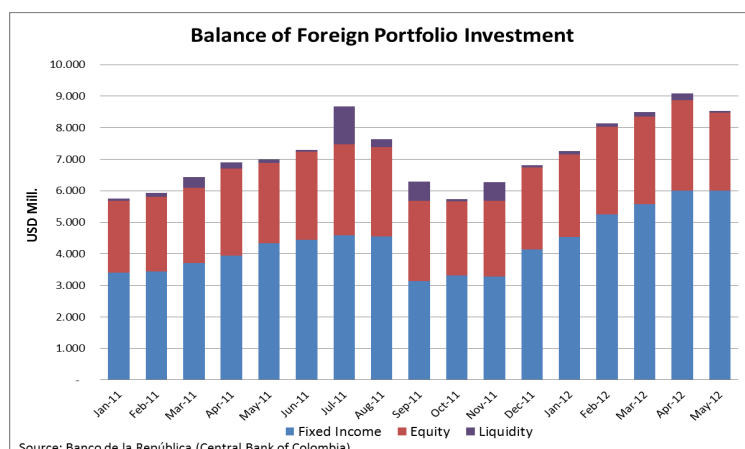
Section 3.2 shows that in the presence of an exchange rate transmission channel, reserve requirements are more relevant when the exchange rate pass-through is higher and when the currency depreciates after an upward movement in them. The pass-through ( $B$ ) is low and has been going down in Colombia during the last decade (Vargas (2011)). Additionally, the interest rate-sensitive capital flows are mostly net inflows from external debt (which depend on lending rates) and portfolio investment, which typically goes to fixed income and equities more than to bank deposits (Figure 4). So, it is probable that the exchange rate response to an increase in reserve requirements is nil ( $s_z \approx 0$ ) or even negative ( $s_z < 0$ ). Therefore, unless the cost of the distortions introduced by reserve requirements is low ( $\rho$  low), their optimal adjustment after a macroeconomic shock should be small.

When the CB has private sector leverage in its loss function, the results of the previous section suggest that reserve requirements are more relevant when their increase reduces the deposit interest rate. As mentioned, this does not seem to be the case in Colombia. Nonetheless, from the first order conditions of the CB problem, it follows that in the presence of excess leverage ( $c > 0$ ), if an increase in reserve requirements does not reduce deposit rates ( $i_z^d \geq 0$ ), optimal reserve requirements will be larger, the weaker the transmission from the policy interest rate to lending rates<sup>14</sup>.

<sup>13</sup>These results are in line with the conclusions of Glocker and Tobin (2012b). They find that reserve requirements play a valuable macroprudential role in the presence of financial frictions and of an explicit financial stability objective of the CB.

<sup>14</sup>From equation (36) it follows that  $\frac{\partial z}{\partial i_z^d} = \frac{\gamma c c_1 x_{id} i_z^d}{\rho (x_{id} i_z^d + x_{il} i_z^l)^2} (i_z^d x_{id} + x_{il} i_z^l) < 0$  under the conditions mentioned.

FIGURE 4



In this context, the use of reserve requirements is justified occasionally when supply credit shocks are large and the transmission of the policy interest rate to the lending rates is lowered. This helps to explain the increase in reserve requirements in 2007, since the economy experienced a large credit supply shock and the transmission of the increases in the policy rate to the lending rates was sluggish.

Another explanation for the infrequent use of reserve requirements in Colombia has to do with the uncertainty about their macroeconomic effects relative to the uncertainty about the impact of changes in the policy rate. When the effects of reserve requirements are more uncertain than the policy rate's, their use should be limited to large shocks. In this case, the Brainard principle<sup>15</sup> is less restrictive.

## 6. CONCLUSIONS

From the perspective of optimal monetary policy, it is difficult to establish a general procedure for the use of reserve requirements in an IT regime. As reserve requirements act as distortionary taxes, their volatility is costly for the economy. Hence, in principle, it is undesirable to move them frequently and in large magnitudes. Theoretically, the use of reserve requirements is justified when monetary policy has several transmission channels, the CB has additional objectives such as financial stability and, especially, when their effects differ from the policy rate's. However, the relevance, magnitude and direction of the movements of reserve requirements depend on the parameters of the economy and the shocks that affect it. Depending on these factors, reserve requirements may act as complements or substitutes of the policy interest rate.

As a result, each CB should determine the relevance and the way to use reserve requirements. For example, in Colombia, in 2007 the CB increased reserve requirements and the policy interest rate to handle a large credit supply shock, low transmission of policy rate to lending rates and high concern for financial stability. In 2010, in Turkey, the CB decreased the policy interest rate and increased reserve requirements, given short term capital inflows, appreciation of the currency,

<sup>15</sup>Policy decisions should exhibit conservatism in the face of uncertainty about the parameters of the economy.

high credit growth and maturity mismatches in the financial system, with low inflation risk and an explicitly high concern for financial stability (Binici and Y  r  jkoglu (2011)).

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