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The Macroeconomic Effects of Reserve Requirements ^{*}

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ABSTRACT

Monetary authorities in emerging markets are often reluctant to raise interest rates when dealing with credit booms driven by capital inflows, as they fear that an increase attracts even more capital and appreciates the currency. A number of countries therefore use reserve requirements as an additional policy instrument. The present study provides evidence on their macroeconomic effects. We estimate a vector autoregressive (VAR) model for the Brazilian economy and identify interest rate and reserve requirement shocks. For both instruments a discretionary tightening leads to a decline in domestic credit. We find, however, very different effects for other macroeconomic aggregates. In contrast to interest rate policy, a positive reserve requirement shock leads to an exchange rate depreciation and an improvement in the current account, but also to an increase in prices. The results suggest that reserve requirement policy can complement interest rate policy in pursuing a financial stability objective, but cannot be its substitute with regards to a price stability objective

Keywords: Reserve Requirements, Capital flows, Monetary Policy, Business Cycle
JEL Classification: E58, E52, F32, F41 .

RÉSUMÉ

Les autorités monétaires des pays émergents hésitent souvent à augmenter leurs taux d'intérêt face à un boom du crédit financé par des entrées de capitaux, parce qu'elles craignent qu'une augmentation attire encore plus de capital et apprécie la monnaie. Par conséquent, plusieurs pays utilisent les réserves obligatoires comme un instrument politique supplémentaire. Cette étude examine leurs effets macroéconomiques. Nous estimons un modèle vectoriel autorégressif et identifions des chocs de taux d'intérêt et de réserves obligatoires. Pour les deux instruments, un resserrement discrétionnaire mène à une baisse du crédit domestique. Cependant, nous trouvons des effets très différents pour d'autres agrégats macroéconomiques. Contrairement à la politique de taux d'intérêt, un choc positif de réserves obligatoires mène à une dépréciation du taux d'intérêt, à une amélioration du compte courant, mais aussi à une augmentation des prix. Les résultats suggèrent que la politique de réserves obligatoire peut venir en complément de la politique de taux d'intérêt dans la poursuite d'un objectif de stabilité financière, mais ne peut pas la substituer quant à un objectif de stabilité de prix.

Mots-clés: : réserves obligatoires, flux de capitaux, politique monétaire, cycle économique

Codes classification JEL : E58, E52, F32, F41.

1 Introduction

A substantial number of central banks in emerging markets use reserve requirements on bank deposits as an additional policy instrument, in conjunction with a conventional interest rate policy. The present study provides empirical evidence on the macroeconomic effects of reserve requirement changes in this context.

There are several motivations for central banks to vary reserve requirements over the cycle. First, emerging countries are often reluctant to increase interest rates in response to credit booms financed by capital inflows: they fear that higher interest rates attract even more capital inflows and appreciate the currency.¹ In this vein, reserve requirements are discussed as an alternative way to tighten domestic credit conditions (Reinhart and Reinhart, 1999, Montoro and Moreno 2011, Terrier et al., 2011). Since reserves are often remunerated below market rates, an increase in reserve requirements acts as an implicit tax on the banking sector and widens the spread between deposit and lending rates. The higher spread makes it less attractive for foreign investors to lend to domestic banks and at the same time makes it more expensive for the domestic sector to borrow from banks. The argument implies that reserve requirement increases may achieve a contraction in domestic credit, without attracting capital inflows and appreciating the currency. The Turkish central bank, for instance, considers the interest rate as the main instrument for price stability and reserve requirements as the main instrument for financial stability (Başçı, 2010). In this context, reserve requirements and reserve remuneration are explicitly used as a macroprudential tool. Other countries that adjust reserve requirements with a similar objective as Turkey are, among others, Brazil, Croatia, Columbia, Peru, and Russia (see Lim et al. 2011 for further details). An empirical evaluation of how reserve requirement changes affect domestic credit and external variables is to our knowledge still missing.

Second, reserve requirement policy can also serve to stabilize inflation. An increase in reserve requirements reduces the money multiplier. If the monetary authority keeps the monetary base stable, a reserve requirement increase reduces broad money and raises the interest rate level, which should lower inflation. Today, most countries have an interest rate or exchange rate target to which the monetary base adjusts endogenously. Under such a framework the effects of reserve requirement increases on inflation are therefore less clear from a theoretical perspective. Nonetheless, market observers perceive that some countries, for example China, use reserve requirement policy as a substitute for interest rate policy to contain inflationary pressures.² The implied argument is that reserve requirement increases may be able to cool down the economy and thereby also lower prices. But also the opposite argument is made: a loosening of reserve requirements in response to capital outflows may be a way to stimulate the economy without

¹Calvo and Reinhart (2002), Calvo et al. (1994) and others discuss the reasons why emerging countries may display a “fear of floating” and are wary of large capital inflows.

²For example, Financial Times (2011) writes that “China ordered banks to hold more of their deposits on reserve [...] in a move [...] aimed at tackling inflation”.

creating inflation (see for example Montoro and Moreno, 2011). Again, an empirical evaluation of the relationship between reserve requirements, overall macroeconomic activity, and inflation seems to be missing.³

The main contribution of the present paper is to provide empirical evidence on the effects of reserve requirement changes on key macroeconomic variables. In particular, we are interested in the effect of reserve requirement shocks on (a) domestic credit conditions, (b) the external balance and the exchange rate, and (c) domestic inflation and overall macroeconomic activity. To that purpose, we estimate a structural vector autoregressive (VAR) model for the Brazilian economy and identify interest rate and reserve requirement policy shocks. Brazil is well suited for a such study: first, it follows a homogeneous monetary policy framework since 1999 (when it adapted inflation targeting) with the short term interest rate as the main instrument. A homogeneous policy framework is important, because the effects of reserve requirement changes depend importantly on the overall central bank policy framework, as we will argue below. Second, Brazil has a long history in the application of time-varying reserve requirements. As a consequence there is sufficient variation in the reserve requirement ratio, which allows the use of modern time series tools. Finally, the Brazilian authorities provide an excellent supply of key macroeconomic time series data at a monthly frequency. Many other countries that use reserve requirements as a policy instrument lack at least one of these characteristics.

Since both interest rate and reserve requirement policy changes affect nominal bank reserves, we need to account for simultaneity and aim to disentangle the two policy shocks with a novel identification scheme, based on a combination of sign and zero restrictions. Different movements in nominal bank reserves in response to either shock are crucial in our identification approach. To characterize the overall stance of the reserve requirement policy, other variables in addition to the aggregate reserve ratio may have to be considered, such as the rate of reserve remuneration and the type of funding to which the requirement applies. We therefore also provide a brief overview of the reserve requirement system of Brazil and discuss alternative measures of the reserve requirement policy stance in some detail.

To preview our results, we find that both interest rate and reserve requirement increases lead to a contraction in domestic credit, but have very different effects on other macroeconomic variables. A discretionary increase in reserve requirements leads to an exchange rate depreciation and an improvement in the current account, but to an increase in the price level. A discretionary interest hike leads to lower prices, but an exchange rate appreciation and a deterioration of the current account. Our results indicate that in Brazil, reserve requirement increases are a way to reduce credit growth without appreciating the exchange rate, but are an inadequate policy step

³Much of the current discussion focuses on the question in how far reserve requirement policy can complement conventional interest rate policy to obtain economic and financial stability, but reserve requirements have served a broad set of purposes historically. See our discussion in Section 3 and Goodfriend and Hargraves (1983) for an historical overview about reserve requirement policy in the United States. Montoro and Moreno (2011) and Terrier et al. (2011) discuss the use of reserve requirements as a macroprudential tool in Latin America.

to reduce inflation.

The results also shed light on the importance of the bank lending channel. It is challenging to evaluate the importance of the bank lending channel empirically with macroeconomic time series data, because it is difficult to distinguish between credit demand and credit supply effects when considering the responses to policy rate movements (Kashyap and Stein, 2000).⁴ With the interest rate as the principal policy instrument, reserve requirements act mainly as a tax on deposits and do not directly affect other forms of lending. For reserve requirements to have macroeconomic effects two conditions need to be fulfilled. First, banks cannot easily find alternative sources of funding that are not subject to reserve requirements. Second, the private sector cannot easily substitute bank credit with other sources of financing. As regards our empirical results, the fall in domestic credit implies that taxed deposits cannot be perfectly substituted by other means of financing. Moreover the effect on macroeconomic activity and inflation shows that the non financial sector cannot perfectly substitute bank credit as a form of financing. Our results therefore indicate that the bank lending channel has some macroeconomic importance in Brazil.

Regarding previous work, there is a large literature that uses structural VARs to identify monetary policy shocks and analyzes their effects on macroeconomic variables (see Christiano et al. 1999 for an overview and Mallick and Sousa, 2011, Catão and Pagan, 2011, Luporini, 2008 and Kamal, 2010 for applications to Brazil). Despite the fact that a number of emerging countries' central banks use reserve requirements as an additional policy instrument, the methods have so far not been applied to analyze the consequences of reserve requirement shocks. The empirical literature has mainly focused on partial equilibrium aspects of reserve requirement policy and has not investigated the joint dynamics of macroeconomic variables. Gelos (2009) looks at a sample of Latin American countries and finds that higher reserve requirements increase banking spreads. As far as Brazil is concerned, studies have estimated the effect of reserve requirement changes on banks' stock returns (Carvahlo and Azevedo, 2008) and banking spreads (Takeda et al., 2003, Cardoso, 2004). Related studies for other emerging countries include Vargas et al. (2010), Cerda and Larrain (2005), Betancourt and Vargas Herrera (2008), Saade and Pérez (2009) and Grosz et al. (2008). All studies focus on the credit market and do not look at the effects on external variables, aggregate macroeconomic activity, or inflation. Loungani and Rush (1995) investigate the effects of reserve requirement changes on investment and output for the United States in a single equation framework, but do not account for the contemporaneous interactions between interest rate and reserve policy and do not consider the effects on external variables.

⁴In response to a monetary contraction, bank credit can fall because of lower credit demand that derives from the generally higher interest rate level and lower economic activity, but is unrelated to the funding costs structure of commercial banks. Many studies (see Takeda et al. 2003 for Brazil) have therefore focused on the cross-sectional dimension, exploiting heterogeneities in the funding composition of banks. Cross-sectional microstudies allow to assess whether a bank lending channel is present, but it is not straightforward to draw conclusions on its macroeconomic importance.

The study is also related to the literature that studies the effects of unconventional monetary policy instruments on macroeconomic activity and the interaction between monetary and macroprudential policy in advanced economies (Baumeister and Benati, 2010, Giannone et al. 2010). In particular, there is a close link between reserve remuneration policy (Kasyhap and Stein, 2011, Ireland, 2011) and the level of reserve requirements. Both a raise in reserve requirements and a decrease in the remuneration rate act as an increase in the implicit tax on banks. An empirical evaluation of unconventional central bank policy and reserve remuneration is, however, challenging, as the measures have only been recently introduced and their introduction correlates with the occurrence of distortions in the financial sector during the global financial crisis.

In the remainder, Section 2 reviews the theory regarding the effects of reserve requirement changes on macroeconomic activity and the interaction with interest rate policy. Section 3 discusses the policy framework of the Brazilian Central Bank, with special attention to the design of the reserve requirement system. Section 4 presents the econometric specification and details the identification strategy. The main results are in Section 5. Extensions and diagnostic checks are reviewed in Section 6. Section 7 summarizes and concludes.

2 Review of the Transmission Channel of Reserve Requirements

In the present section we provide a short discussion of the transmission channel of reserve requirement changes. We first review how the general monetary framework and financial imperfections, in particular the bank lending channel, affect the transmission on domestic and external variables. We then discuss theoretical predictions regarding the effects of reserve requirement changes on credit conditions, external variables, and domestic macroeconomic activity. The discussion remains informal and draws on previous theoretical work, in particular on Glocker and Towbin (2012) where we analyze the effects of reserve requirements in a DSGE model for a small open economy.⁵

2.1 The Role of Monetary Policy

Reserve requirements are the minimum percentage of deposits that banks need to keep as reserves. This part of deposits cannot be used to provide private credit or to buy securities. Higher reserve requirements therefore reduce the money multiplier: For a given monetary base, broad money will decrease with higher reserve requirements.⁶

⁵For other theoretical work on the effects of reserve requirements on macroeconomic variables see for instance, Baltensperger (1982), Cifuentes (2001), Edwards and Vegh (1997), Horrigan (1988), le Fort (1998), Reinhart and Reinhart (1999), Siegel (1981), Souza-Sobrinho (2010).

⁶If we abstract from cash holdings, the following relationship holds between the monetary base R , broad money D (deposits) and the reserve requirements ratio μ : $\mu \cdot D \leq R$. If the inequality constraint binds, the

If the central bank targets quantities and keeps the monetary base constant, the effects of an increase in reserve requirements are analogous to a standard monetary contraction. Higher reserve requirements increase the level of interest rates. In order to fulfill the reserve requirements without reducing credit extended, banks need to attract more deposits, which drives up deposit rates. The increased marginal funding costs in turn will drive up lending rates as well and raise the general level of interest rates.

If the central bank sets the price of money and targets a specific interest rate, we expect very different effects of an increase in reserve requirements. In order to counter a potential deviation of the policy rate from the target, the central bank needs to increase the monetary base and thereby accommodates the contractionary effects of the reserve requirements hike. In relatively simple models reserve requirement changes are neutral if the central bank targets interest rates (Horrigan, 1988). We expect, however, real effects if reserves are not remunerated or at least remunerated below the market rate (Glocker and Towbin, 2012 and Reinhart and Reinhart, 1999). In this case higher reserve requirements act as a tax on bank deposits. As financial intermediation becomes more costly, spreads between lending and deposit rates should rise. If the central bank stabilizes the interbank rate, we expect lending rates to increase and deposit rates to fall, as the stable interbank rate typically lies between deposit and lending rates. Under an interest rate targeting framework, reserve requirement changes are therefore unlikely to affect the general level of interest rates, but may affect interest rate spreads.

Figure 1 provides evidence of accommodative interest rate policy in Brazil. The lower middle panel displays the path of total nominal bank reserves. Movements in the required reserve ratios, displayed in the upper right panel, are positively correlated with movements in nominal reserves.⁷ For example, the tightenings of reserve requirements in 2002/2003 and 2009/2010 are followed by increases in compulsory reserves, consistent with the endogenous expansion of the central bank liquidity.

2.2 The Role of the Bank Lending Channel

As reserve requirements typically apply only to commercial banks, the effects of reserve requirement changes on the general economy depend crucially on the importance of bank lending and in particular on the bank lending channel of monetary policy (Kashyap and Stein, 2000, Bernanke and Blinder, 1989).

In order for reserve requirement changes to have real effects, two conditions need to be fulfilled: The first condition is that deposits cannot be substituted easily as a funding source. Otherwise, banks could compensate the higher deposit funding costs by other financing means such as wholesale funding. Robitaille (2011) analyzes the effects of reserve requirement changes on banks' liability structure in Brazil and finds evidence that banks react to higher reserve

money multiplier is $1/\mu$.

⁷Section 4 discusses the data sources in more detail.

requirements by moving away from deposit funding to issuing more certificates of deposits. In general, we would not expect any macroeconomic effects if alternative funding sources are perfect substitutes for deposit funding.

The second condition is that firms cannot substitute bank credit with other financing sources easily. If bank lending could be substituted easily, a reserve requirement increase would lead to a decrease in bank credit that would be compensated by an increase in other types of liabilities, for example capital market funding, leaving investment decisions and private sector assets unaffected. Motoki and Funchal (2009) and Zonenschain (1997) provide an overview on the importance of bank funding for firms in Brazil and find bank funding to be important.

2.3 Theoretical Predictions

In the following we review the theory regarding the effects of reserve requirement changes on credit conditions, external variables, and the domestic macroeconomy under an interest rate policy framework.

We start with domestic credit conditions. If deposits that are subject to reserve requirements are not perfectly substitutable with other sources of funding, higher reserve requirements increase marginal costs for banks. We therefore expect an increase in the lending - deposit rate spread and a fall in aggregate credit.

The third panel of Figure 1 displays two aggregate measures for reserve requirement ratios as well as the interest rate spread between the lending and the deposit rate.⁸ The spread and the aggregate reserve requirement measures co-move closely. Between 1999:7 and 2000:4 the decline in reserve requirements is associated with a fall in the spread. The rise in reserve requirements between 2001:10 and 2003:2 coincides with an increase in the spread. A similar pattern emerges for the recent loosening of requirements between 2008 and 2009. The pattern is consistent with the hypothesis that reserve requirements do have an effect on banking spreads, but it is difficult to draw any conclusion on the macroeconomic consequences.

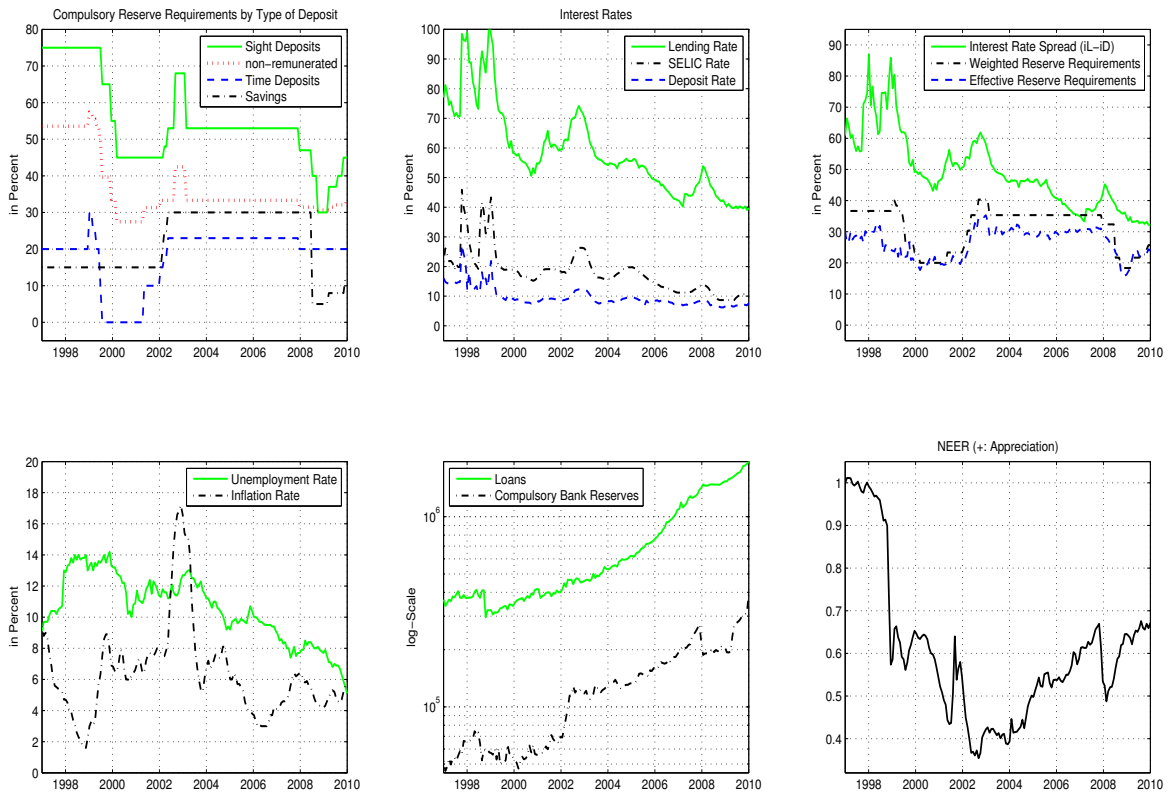
As far as external variables are concerned, we expect that an increase in reserve requirements triggers an exchange rate depreciation and capital outflows (see for instance Reinhart and Reinhart, 1999, Moreno and Montoro, 2011). If the key assumption that a lot of funding has to be intermediated by banks that are subject to reserve requirements is correct, the fall in deposit rates decreases the attractiveness to invest in the country from the point of view of foreign investors. Capital flows out and the exchange rate depreciates.

Regarding the effect on the domestic macroeconomy, the overall effects of reserve requirements on economic activity and inflation are ambiguous from a theoretical perspective (Glocker

⁸Banking spreads in Brazil are exceptionally high by international standards (Gelos, 2009). There is a debate to what extent the high level of reserve requirements can explain the high spread. Cardoso (2004), de Souza Rodrigues and Takeda (2004), Souza-Sobrinho (2010) and Carvalho and Azevedo (2008) find a role for reserve requirements, whereas Nakane and Koyama (2001a, 2001b) do not find a significant effect.

and Towbin, 2012).⁹ If we focus on the first-round, partial equilibrium, effects of a reserve requirements hike, we expect that demand of borrowers and lenders move in opposite directions/ The fall in deposit rates should discourage savings and increase lenders' spending. The raise in lending rates should discourage spending by borrowers. The effect on total economic activity will depend on the relative strength of the two responses and general equilibrium effects. A similar argument can be made for the overall effect on inflation. Reserve requirements also act as an implicit tax on deposits and may increase inflation trough a cost channel. The predicted exchange rate depreciation tends to push prices up through higher import prices. The sign on the inflation reaction will therefore depend on the overall effect on aggregate demand, banking costs, and exchange rate pass-through.

Figure 1: Macroeconomic Variables in Brazil, 1997-2010



Remarks: The figure reports statutory reserve requirements next to key macroeconomic variables. The first panel reports the statutory reserve requirements for sight (*depósitos a vista*), time (*depósitos a prazo*) and saving deposits (*depósitos de poupança*). For each of the three categories, the numbers include the additional requirements (*exigibilidade adicional*). Next to the statutory requirements, panel 1 and panel 3 show our three measures for the reserve requirement policy: (1) the *Weighted Non-Remunerated Reserve Requirements* measure (shown by means of the red dotted line in the first panel), (2) the *Effective Reserve Requirements* measure (represented by the blue dashed line in the third panel) and (3) the *Weighted Reserve Requirements* measure (represented by the black dashed dotted line in the third panel). The SELIC (*Sistema Especial de Liquidação de Custódia*) rate is an overnight interbank rate and the key policy instrument of the Brazilian monetary authority. The interest rate spread shown by means of the green line in the third panel is the difference between the lending and the deposit interest rates as shown in the second panel. The variable for central bank reserves is the sum of private banks' reserves on saving, time and sight deposits held at the central bank. Further information concerning the data and the sources can be found in appendix A.

⁹Evidence from quantitative simulations is available in the cited paper and in an appendix available on request.

3 Central Bank Policy in Brazil

Section 3.1 provides a brief overview over the monetary policy in Brazil in general and discusses important regime changes. Section 3.2 discusses reserve requirement policy.

3.1 Monetary Policy in Brazil

Monetary policy in Brazil has experienced fundamental changes over the last thirty years (BIS, 1998, Bodganski et al., 2001, Lima et al., 2007). The high inflation episodes of the late 1980s led to a series of inflation stabilization attempts, of which most, however, were not successful. The Real Plan (*Plano Real*) in 1994 brought about a sustained decline in inflation. The plan involved a de-indexation of the economy to reduce inflation inertia, the introduction of quarterly targets for monetary aggregates to stabilize inflation expectations and the adoption of a floating exchange rate. After the Mexican crisis in 1995 the floating exchange rate regime was abandoned and replaced with a crawling peg. While Brazil weathered the Asian crisis well, Russia's 1998 default had severe negative spillover effects to Brazil. Investors that previously displayed confidence in Brazil's economy lost faith in the government's ability to maintain the crawling peg. The crawling peg was abandoned in January 1999 and in July a formal inflation targeting framework was adopted.

The inflation target is set by the National Monetary Council every June for the next two years. The Monetary Policy Committee (Copom) decides on the central bank's policy rate, which is the overnight interbank rate or SELIC (*Sistema Especial de Liquidação de Custódia*) rate. The SELIC rate is steered by open market operations. As can be seen in Figure 1, yearly inflation has been below 10% for most of the time. An exception is the period between 2002 and 2003 where a high level of uncertainty prevailed as a result of the election of Luiz Ignácio Lula da Silva (2002-2010) as successor of Henrique Cardoso (1995-2002) as president of Brazil, a domestic energy crisis, and Argentina's default. In response to the high level of uncertainty, capital fled out of the country and the nominal exchange rate depreciated sharply. This in turn created severe inflationary pressures. President Lula da Silva pledged to adhere to the inflation targeting regime and inflation could be stabilized afterwards. The central bank has initiated several policy tightenings through interest rate increases, in particular, in 2004, in 2008 and again within the aftermath of the financial crisis in 2011 (see Figure 1).

3.2 Reserve Requirement Policy in Brazil

Under the present inflation targeting framework the reserve requirement policy has been communicated as a tool to achieve financial stability and to control credit fluctuations. In its inflation report the central bank discusses the use of reserve requirements as a macroprudential tool to "attenuate fluctuations in the credit volume over the economic cycle" (Banco Central do Brazil,

2011, p.99),¹⁰ in particular in the context of capital inflows. Furthermore, during the recent financial crisis reserve requirements have been lowered to increase liquidity in the banking system (Jornal do Comércio do Rio de Janeiro, 2009, Montoro and Moreno, 2011) and, through the use of heterogeneous reserve requirements, to transfer liquidity from big banks to small banks (Robitaille, 2011 and Terrier et al., 2011).

Historically, reserve requirements have served a broad set of purposes and have a long history.¹¹ Cardoso (2004) argues that until 1993 reserve requirements served mainly as an instrument to tax bank profits that accrued with high inflation rates. Reserve requirements have also been used for distributional purposes, with required ratios being higher for banks located in richer regions of the country (Carvalho and Azevedo, 2008). Under the Real plan in the mid nineties, reserve requirements had an explicit monetary policy purpose. Requirements were increased as part of a set of measures to control accelerating inflation and reduce liquidity (Carvalho and Azevedo, 2008 and Robitaille, 2011). The current high compulsory reserve holdings are partly a legacy of this period (OECD, 2009).

Given its various objectives, the characteristics of reserve requirements as a policy instrument appear closer to those of standard fiscal policy tools than to those of an interest rate policy. Whereas the main aim of interest rate policy is to stabilize prices and the business cycle, reserve requirement and fiscal policy usually also pursue distributional or microeconomic, and potentially distortive, objectives apart from business cycle stabilization.

4 Empirical Model and Identification

Section 4.1 discusses the model specification and data sources, in particular we propose three different measures for reserve requirement policy. Section 4.2 presents our identification scheme. Section 4.3 describes the inference procedure.

4.1 Model Specification and Data

We estimate a Bayesian vector autoregressive (BVAR) model of the form:

$$\mathbf{y}_t = \mathbf{\Psi}\mathbf{x}_t + \sum_{i=1}^p \mathbf{A}_i \mathbf{y}_{t-i} + \mathbf{e}_t, \quad \text{with} \quad \mathbf{e}_t \sim N(\mathbf{0}, \mathbf{\Sigma}) \quad \forall t = 1, \dots, T \quad (1)$$

\mathbf{y}_t is a vector of endogenous variables, \mathbf{x}_t is a vector of exogenous variables, \mathbf{e}_t is a reduced-form error term with variance-covariance matrix $\mathbf{\Sigma}$, p is the lag length and \mathbf{A} and $\mathbf{\Psi}$ are coefficient matrices.

Our sample comprises monthly data that cover the period from 1999:7 to 2010:12. We choose

¹⁰Translation by authors.

¹¹Fernandes (1992) mentions that reserve requirements were first introduced in Brazil in 1932.

the implementation of the inflation targeting regime as the starting date in order to ensure a homogeneous monetary policy framework.

4.1.1 Measures for Reserve Requirement Policy

The current reserve requirement policy in Brazil is complex. Reserve requirement ratios vary across different types of deposits. Additional policy parameters include reserve remuneration, exemption thresholds, and deductibles. We propose three different reserve requirement policy measures and provide a brief overview of the reserve requirement system in Brazil in this context, mainly based on Robitaille (2011), Banco Central do Brasil (2010, 2011) and Terrier et al. (2011).

The first measure is a weighted average of all reserve requirements (entitled *Weighted Reserve Requirements*). Different reserve requirement ratios apply for sight deposits (*depósitos a vista*, 43% plus 12% additional requirements (*exigibilidade adicional*) in December 2010), saving deposits (*depósitos de poupança*, 20% plus 10% additional requirements in December 2010) and time deposits (*depósitos a prazo*, 20% plus 12% additional requirements in December 2010).¹² Figure 1 displays the time path of total requirements on sight, saving and time deposits. Our first measure for aggregate reserve requirement policy is the weighted average of the three series, also displayed in Figure 1.¹³

The second measure is *Weighted Non-Remunerated Reserve Requirements*. Sight and saving deposits are not remunerated or at a rate substantially below the SELIC rate. One part of time deposit reserves has to be invested in government bonds, the other part is remunerated at the SELIC rate (Robitaille, 2011). The aforementioned additional requirements on sight and saving deposits earn the SELIC rate. The second measure is a weighted average of reserve requirements on sight and saving deposits excluding the additional requirements, again displayed in Figure 1.

The third measure is called *Effective Reserve Requirements*. Small banks are partly exempted from reserve requirement regulation. An exemption threshold exists on a variety of deposits above which compulsory reserve requirements apply. If a bank's deposit volume is below the exemption value, the reserve requirement regulation becomes obsolete.¹⁴ As a result, reserve requirements are progressive in bank size and effective reserve requirement ratios can be substantially below statutory ratios. The Brazilian central bank has used variations in the exemption threshold as an additional policy instrument and increased its size for time deposits substantially as a response to the global financial crisis.¹⁵ The weighted reserve requirements

¹²See for instance Banco Central do Brasil (2010)

¹³The weights are 26.6% for time, 30.9% for saving and 52.4% for sight deposits, based on the average holdings between 1999-2010.

¹⁴As of December 2007, Brazil had 101 banks out of which only 41 were required to hold reserves at the central bank (Robitaille, 2011).

¹⁵In particular this threshold was raised from 100 million to two billion Reais for time deposits and to one billion Reais for the additional requirements (OECD, 2009). In addition, during the crisis there were further deductibles if large banks lend to small banks, which allowed the central bank to distribute liquidity (Robitaille, 2011).

measure only captures policy changes of statutory reserve requirements. It ignores the policy changes that are specific to changes in the exemption thresholds and deductibles. In order to include also these policy changes into an overall measure for the reserve requirement policy, we calculate a measure for aggregate effective reserve requirements as total reserves over total deposits. As can be seen in Figure 1, our effective reserve requirements measure tends to be below the weighted reserve requirement measure, but follows broadly the same cyclical pattern.

Each measure has its own advantages and disadvantages. Weighted reserve requirements characterize the aggregate stance of reserve requirements, but mix different rates of remuneration. The weighted non-remunerated reserve requirement measure focuses on a segment of reserve requirements where the remuneration is homogeneous, but neglects changes in other reserve requirements. While we expect the macroeconomic effects of non-remunerated reserves to be stronger because of the higher implicit tax on deposits, even reserves that are remunerated at market rates can affect the distribution of lending. In addition, it deprives banks of a potential mark-up they charge on lending rates and may reduce profits. Both weighted measures neglect changes in the deductible and the exemption threshold. While the effective reserve requirement ratio captures the deductible and the exemption threshold, it is not directly controlled by the central bank, as it is also affected by changes in the relative weight of the respective deposit categories. In what follows, we use weighted total reserve requirements as our main policy variable and compare it to the other two measures.

4.1.2 Other variables

The vector of endogenous variables includes the consumer price index (CPI), the unemployment rate, the spread between deposit and lending rates, a measure for reserve requirement policy (described above), the policy (SELIC) interest rate, the log of the nominal effective exchange rate, the log of nominal total credit, the current account to GDP ratio and finally the log of nominal compulsory bank reserves. The current account measures net capital inflows, being the flip side of the financial account. Unemployment is our main measure for economic activity. As a robustness check, we will use industrial production and the gross domestic product as alternative measures. Total bank reserves are computed as the sum of compulsory reserves due to sight, saving and time deposits, including additional requirements. In section 6 we show that our results are robust to alternative measures of central bank liquidity.¹⁶

In order to control for external effects we include the federal funds rate and a commodity price index with two lags as exogenous variables. The vector of exogenous variables further includes as deterministic variables a quadratic time trend, monthly dummies to control for seasonal affects, and a level dummy between 2002:7 and 2003:7 to control for the financial market turbulences

¹⁶For all measures, we abstract from accounting for reserves borrowed over the discount window. Since the adoption of inflation targeting, discount lending does not play an operational role in the implementation of monetary policy and the amount extended is small.

associated with the energy crisis, the Argentinean debt crisis and the election of Lula da Silva as president. We choose a lag length of two¹⁷ and estimate the parameter matrices of the BVAR in equation (1) using Bayesian techniques as outlined in Uhlig (1994) using an uninformative Normal-Wishart prior density for the coefficient matrices and the variance-covariance matrix.

4.2 Identification

We can think of the one step ahead prediction error \mathbf{e}_t as a linear combination of orthonormal structural shocks $\mathbf{e}_t = \mathbf{B} \cdot \mathbf{v}_t$, with $E(\mathbf{v}_t' \mathbf{v}_t) = \mathbf{I}$. The matrix \mathbf{B} describes the contemporaneous response of the endogenous variables to structural shocks. With no additional information or assumptions \mathbf{B} is not identified. The only restriction on \mathbf{B} that comes from the data is that the matrix multiplied by its transpose must equal the covariance matrix of the prediction errors $\mathbf{\Sigma} = E(\mathbf{e}_t \mathbf{e}_t') = E(\mathbf{B} \mathbf{v}_t \mathbf{v}_t' \mathbf{B}') = \mathbf{B} \mathbf{B}'$. This leaves many degrees of freedom in specifying \mathbf{B} and further restrictions are necessary to achieve identification.

The challenge for structural VAR models is to find credible restrictions on \mathbf{B} . We pursue a partial identification approach to identify a reserve requirement shock and an interest rate policy shock. The main interest of the present study is how macroeconomic variables respond to unexpected changes in reserve requirements. In order to control for the effects of interest rate policy, we also identify an interest rate shock that is orthogonal to the reserve requirement shock. We identify the two shocks with a combination of timing and sign restrictions. The identification restrictions are summarized in Table 1.

Regarding the timing (or zero) restrictions, we assume that there is a block of “slow moving variables” that does not respond contemporaneously to changes in central bank policy (changes in interest rates and reserve requirements). The block of slow moving variables includes the unemployment rate, the price level, the current account, and the spread between lending and deposit rates. The assumption of a block of slow moving variables is standard in the VAR literature that studies monetary policy and relies on some rigidities in the adjustment of prices and quantities that impede an immediate response of these variables to changes in central bank policy. As we use monthly data the imposed delay is relatively short.

In order to distinguish the two central bank policy shocks from each other and from shocks that originate from fast moving variables, we complement the zero restrictions with a set of sign restrictions on fast moving variables. The block of fast moving variables, which are allowed to respond to central bank policy shocks within a month, is a set of financial variables and comprises the nominal exchange rate, total credit and central bank reserves. Sign restrictions have been proposed in Canova and De Nicoló (2003) and Uhlig (2005) and narrow down the set of acceptable \mathbf{B} matrices by restricting the sign of the impulse responses of a set of variables to a structural shock. The sign restrictions should be based on well established economic theory,

¹⁷The lag length is chosen by the Schwarz Information Criterion. A Ljung-Box test cannot reject the null-hypothesis of no autocorrelation in the residuals.

while the responses of variables where there is no consensus on the sign of their responses are left unrestricted. We impose the sign restrictions for three months.

A positive reserve requirement shock leads to an increase in central bank reserves and reserve requirements. The assumption implies that monetary policy accommodates the consequences from a reserve requirement increase on interest rates which follows from Brazil's monetary policy framework. If the Brazilian central bank sets the interest rate, it needs to expand nominal reserves in order to avoid an increase in the policy rate. However, our increase in nominal reserves does not impose complete accommodation as pure interest rate targeting would imply, but only that the central bank aims to stabilize the interest rate to some degree.

A positive interest rate shock is associated with a fall in central bank reserves. The restriction on central bank reserves follows from the fact that in order to implement an interest rate increase the central bank needs to withdraw liquidity, which is reflected in lower reserves (see Bernanke and Mihov, 1997 and Uhlig, 2005 for a discussion for Germany and the United States). Both identification restrictions follow directly from the assumption that the central bank steers interest rates by adjusting central bank liquidity and hold for a broad class of models.¹⁸ Note that both the interest rate target and its steering rates through open market operations are crucial for our identification scheme. For example, our identifying assumptions would not be valid for a developing country with thin financial markets, where authorities steer the policy rate by adjusting reserve requirements instead of adjusting base money.

The identification scheme described above allows for an immediate response of the central bank to movements in fast moving variables. A large number of VAR studies identifies interest rate policy shocks with a completely recursive ordering, which imposes that the central bank does not respond immediately to changes in fast moving variables. In our example, such an identification scheme assumes that the central bank does not respond to movements in the volume of credit and foreign exchange market within a month. While such an assumption may be more reasonable for advanced economies, we believe it to be too restrictive for an emerging country, where central banks monitor developments in the financial sector and the exchange rate closely. Second, the ordering of reserve requirement ratios and interest rate policy is not obvious as there are important interactions between reserve requirement and interest rate policy. We therefore prefer the approach outlined above that mixes zero and sign restrictions. An advantage of exact identification schemes is that they usually give more precise impulse response function estimates, as for a given parameter estimate there is unique matrix \mathbf{B} that satisfies the restrictions. All uncertainty derives therefore from sampling uncertainty. Identification based on sign restriction is inexact and there is a set of \mathbf{B} matrices that satisfy the restrictions. Total uncertainty is a combination of sampling and identification uncertainty. The researcher therefore faces a familiar trade-off between less restrictive assumptions and more precise estimates.

¹⁸As an example, we provide a short discussion that motivates the sign restrictions by the results from a dynamic stochastic general equilibrium (DSGE) model in an appendix available on request.

4.3 Computational Implementation

We sample the regression coefficients \mathbf{A}_i and covariance matrix Σ from the posterior distribution.¹⁹ Given the draws, we implement the sign restriction as follows: we compute the Cholesky factorization \mathbf{V} of the covariance matrix with the slow moving variables ordered first. We then multiply \mathbf{V} with an orthonormal matrix \mathbf{Q} ($\mathbf{B} = \mathbf{V}\mathbf{Q}$) and compute candidate impulse responses, where \mathbf{Q} is a block diagonal matrix of the following form:

$$\mathbf{Q} = \begin{bmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{Q}_2 \end{bmatrix} \quad (2)$$

$N_S \times N_S$ $N_S \times N_{F,P}$
 $N_S \times N_{F,P}$ $N_{F,P} \times N_{F,P}$

and N_S is the number of slow moving variables and $N_{F,P}$ is the total number of fast-moving and policy variables. Because \mathbf{Q} is block diagonal the property from the Cholesky factorization \mathbf{V} that slow moving variables do respond immediately to variations in policy and fast moving variables is maintained.²⁰ \mathbf{Q}_2 is a random orthonormal matrix of dimension $N_{F,P} \times N_{F,P}$. Following Rubio-Ramirez et al. (2010) we compute \mathbf{Q}_2 by drawing an independent standard normal matrix \mathbf{X} of size $N_{F,P} \times N_{F,P}$ and apply the QR decomposition $\mathbf{X} = \mathbf{Q}_2\mathbf{R}$. If the corresponding \mathbf{B} matrix implies impulse response functions that are consistent with the sign restrictions for both shocks, we keep the draw and proceed with the next parameter draw until we have 2000 accepted draws. Otherwise, we draw a new \mathbf{Q} matrix until the sign restrictions are fulfilled. We report as coverage bands the 10% and 90% percentile of the distribution.

5 Results

The following section discusses the results for the two central bank policy shocks. Sections 5.1 and 5.2 focus on the impulse response functions for the reserve requirement and the interest rate (SELIC) shock. Section 5.3 summarizes the commonalities and differences of interest rate and reserve requirement shocks and discusses their contribution to the overall economic fluctuations.

5.1 Reserve Requirement Shock

Figure 2 displays the impulse response functions to a one percentage point reserve requirement shock. The solid black line shows the median responses based on the weighted reserve requirements measure.

We start with a discussion of the credit market, where we observe a tightening of lending conditions. In response to the increase in reserve requirements, the spread between the lending

¹⁹ Σ is drawn from an Inverted-Wishart Distribution $IW(\Sigma_{OLS}, T)$, \mathbf{A}_i from a Normal Distribution $N(\mathbf{A}_{i,OLS}, \Sigma)$, where T is the number of observations and subscript *OLS* stands for the OLS estimates.

²⁰Because we are only interested in the responses to interest rate shocks and reserve requirement shocks, the ordering of the slow-moving variables does not matter (Christiano et al. 1999).

Table 1: Identification Restrictions

	RR Shock	SELIC Shock
U	0	0
CPI	0	0
CA	0	0
Spread	0	0
RR	≥ 0	•
SELIC	•	≥ 0
Loans	•	•
NEER	•	•
CB Res	≥ 0	≤ 0

Notes: Zero restrictions apply to the first month, sign restrictions to the first quarter. The variables are: nominal effective exchange rate (NEER), total aggregate credit (Loans), central bank reserves (CB Res), the SELIC rate, reserve requirements (RR), the interest rate spread between lending and deposit rates (Spread), the current account over GDP (CA), the price level as measured by the CPI and finally the unemployment rate (U).

and deposit rate rises and peaks after about 5 months at about 80 basis points. The increase is significant and lasts for more than a year. The rise in the spread is consistent with the effects we would expect from a rise in the implicit tax on deposits. Domestic credit falls initially by about 2.5% and reverts back to zero after about two years.

Turning now to the external sector, we observe a 2% depreciation of the domestic currency and an improvement of the current account by more than 0.2 percent of GDP after half a year. A possible interpretation of the finding is that the increase in the tax makes investing in the domestic economy less attractive, capital flows out and the exchange rate depreciates. The depreciation leads to a gain in external competitiveness, which improves the current account balance.

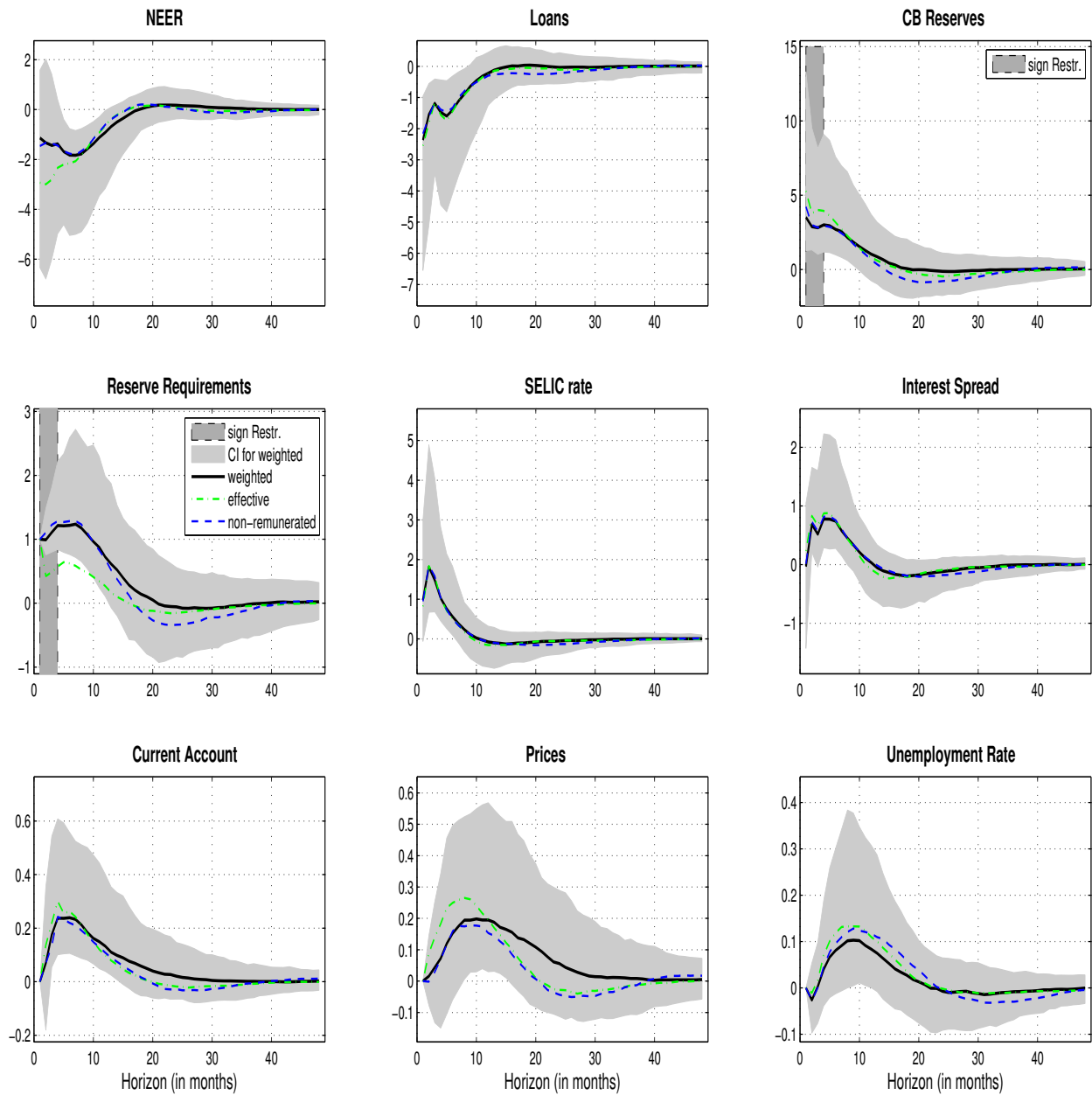
The effects on unemployment and the price level have the characteristics of an aggregate supply shock rather than those of a demand shock. The increase in unemployment coincides with a rise in the price level. Unemployment rises by more than 0.1 percentage points within a year. Prices increase by about 0.2 percent within six months. As discussed in Section 2.1, both the effect on overall economic activity and prices are ambiguous from a theoretical perspective. The results indicate that on the real activity side the effects from a decline in the demand of lenders dominates.²¹ On the price side, inflationary pressures that arise from the exchange rate depreciation and the increase in intermediation costs prevail.

Regarding the interaction between the interest rate and reserve requirement policy, we observe an increase in the SELIC rate, which indicates that the reduction in central bank liquidity that follows from the reserve requirement hike is only partially accommodated through an in-

²¹Although certainly interesting, we cannot investigate the separate responses of consumption and investment or an even finer decomposition of aggregate spending, as they are not available at a monthly frequency.

Figure 2: Reserve Requirement Shock

The figure reports the impulse response functions to a surprise innovation in Reserve Requirements. The shock is identified by restricting central bank reserves (CB Reserves) and reserve requirements to be positive for one quarter as displayed graphically by the dark grey areas. The impulse response functions are shown for a horizon of up to 48 months (4 years). A decrease in the nominal effective exchange rate (NEER) implies a depreciation.



crease in nominal reserves. A possible explanation for the increase is an endogenous response of interest rate policy to higher inflation prospects.

Our results are robust to the use of alternative reserve requirement measures. The impulse response functions based on the non-remunerated reserve requirement measure are shown in Figure 2 by the blue dashed lines. Both quantitatively and qualitatively there are no substantial differences. If we use effective reserve requirements as a measure for the policy stance (dash dotted green line), the results are again very similar.

5.2 Interest Rate Shock

Figure 3 displays the impulse response functions to a positive one hundred basis points shock in the SELIC rate.

The responses of the variables are in line with theoretical prediction of the main stream literature on monetary policy. Our monetary policy shock has the standard features of an aggregate demand shock: unemployment increases, whereas prices fall. The response of unemployment displays a hump-shaped pattern, peaking at about 0.04 percentage points after about half a year and returning to its pre-shock levels after about three years. Prices also respond in a hump-shaped pattern, the dynamic response reaches a trough at minus 0.13 percent after about half a year and flattens out after about three years. Although we have left the sign of the price response unrestricted, we do not observe the “prize puzzle” - an increase in prices after a monetary contraction - that is often present in VARs that study monetary policy (Sims, 1992)²².

Regarding external variables, the results are again in line with the standard theoretical literature. The nominal exchange rate appreciates immediately by a little more than one percent, before depreciating back to its initial level. Blanchard (2005) builds a theoretical model that characterizes the turbulent 2002-2003 period and shows that interest rate increases in Brazil can have perverse effects on exchange rates. If higher interest rates lead to a sharp worsening of macroeconomic conditions, interest rate premia may rise, triggering a capital outflow and an exchange rate depreciation. Our results, estimated over the whole period, indicate an exchange rate path consistent with the predictions of standard open economy models such as Dornbusch’s (1976) overshooting model. The deterioration of the foreign balance is consistent with the effects we would expect from an exchange rate appreciation and the loss in external competitiveness.

The interest shock also has the predicted effects on the credit market. Loans persistently decline by about 1% and the spread between lending and deposit rates rises by about 40 basis points after four months.

Regarding the interaction between the two considered policy instruments, interest rate policy has only weak effects on reserve requirement policy. The reserve requirement ratio tends to fall,

²²A prominent explanation for the price puzzle is that studies omit important variables (see e.g. Banbura et al. 2010). The lack of a price puzzle provides therefore also indirect support to our specification.

Figure 3: Interest Rate Shock

The figure reports the impulse response functions to a surprise innovation in the SELIC rate. The shock is identified by restricting the SELIC rate to react positively and central bank reserves (CB Reserves) to react negatively for one quarter as displayed graphically by the dark grey areas. The impulse response functions are shown for a horizon of up to 48 months (4 years). An increase in the nominal effective exchange rate (NEER) implies an appreciation.

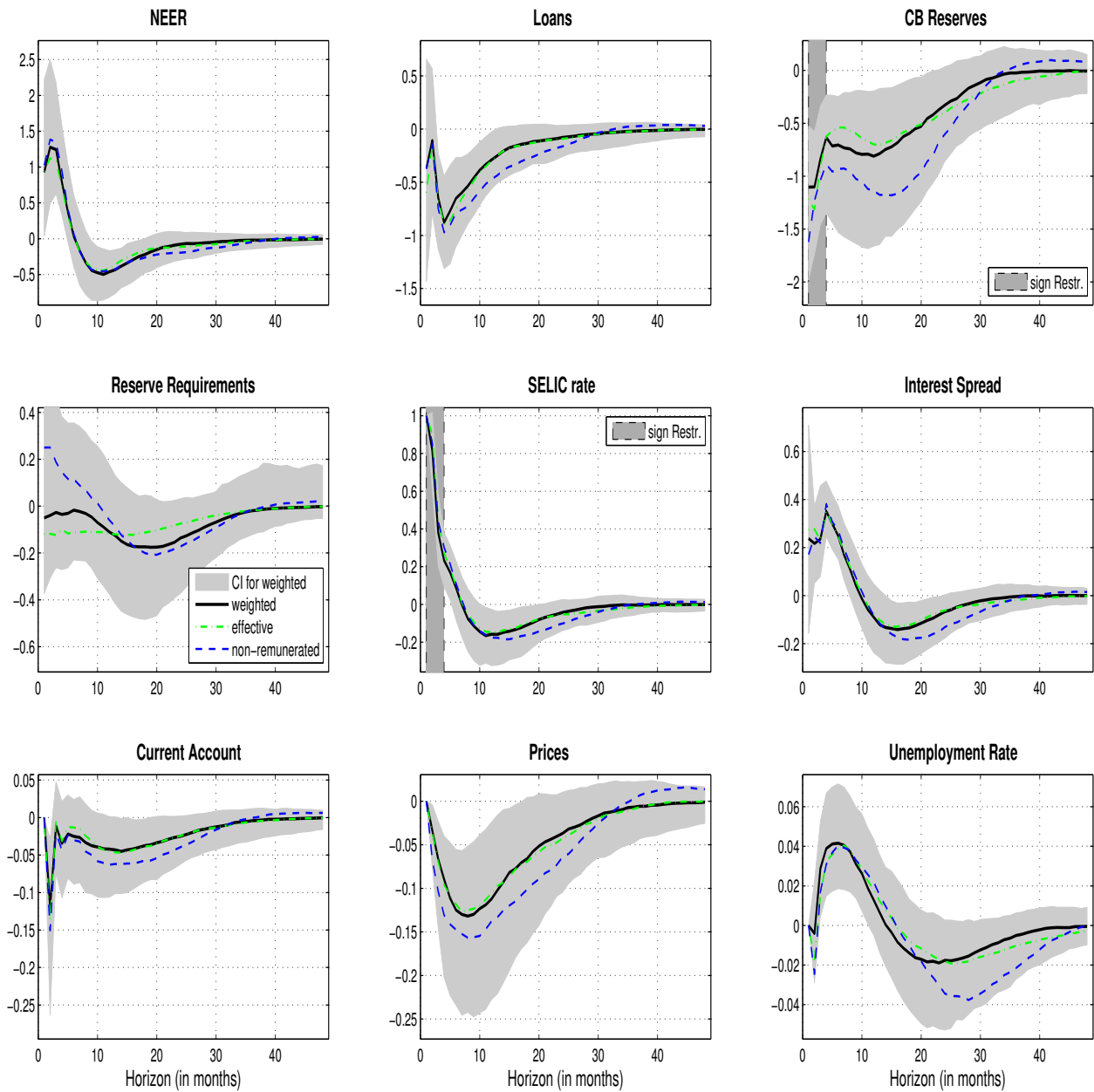


Table 2: Quantitative Impact of Contractionary Monetary Policy - Interest (SELIC) rate and Reserve Requirement (RR) Shock

Loans	SELIC Shock		RR Shock	
	-1	Percent	-1	Percent
NEER	0.59	Percent	-1.14	Percent
CB Res	-2.51	Percent	2.09	Percent
RR	-0.09	Percentage Points	1.03	Percentage Points
SELIC	0.43	Percentage Points	0.23	Percentage Points
Spread	0.19	Percentage Points	0.46	Percentage Points
CA	-0.05	Percentage Points	0.12	Percentage Points
CPI	-0.18	Percentage Points	0.10	Percentage Points
U	0.09	Percentage Points	0.04	Percentage Points

Notes: The numbers shown refer to the reaction of the variables at the initial stage of the shock (one year). The variables are: nominal effective exchange rate (NEER), total aggregate credit (Loans), central bank reserves (CB Res), the SELIC rate, reserve requirements (RR), the interest rate spread between lending and deposit rates (Spread), the ratio of the Current Account (CA) to GDP, the price level as measured by the CPI and finally the unemployment rate (U).

but is not significantly different from zero. A negative response of reserve requirements would be consistent with an endogenous response to the deteriorated credit conditions.

5.3 Reserve requirement and interest rate policy shocks: a comparison

A rise in interest rates and a rise in the reserve requirement ratio are two different possibilities for a central bank to engineer a contraction in credit. Table 2 lists credit “sacrifice ratios”, in particular it addresses the question: what does a one percent reduction in loans achieved either through a tightening of interest rates or reserve requirements imply for the movements in other macroeconomic variables. All reported values are averages over the first twelve months, using the specification with the weighted reserve requirements measure. We observe that the two instruments have very different effects on other macroeconomic variables. The exchange rate, the current account and prices move in opposite directions. An increase in reserve requirements leads to an exchange rate depreciation and a current account surplus, but increases prices. A discretionary interest hike leads to lower prices, but an exchange rate appreciation and a current account deficit. The policy rate has to rise more under an interest rate shock to achieve the required credit reduction, whereas the lending-deposit spread rises by more when the reduction is achieved through an increase in reserve requirements. The result is consistent with the argument that reserve requirement shocks reduce credit mainly through their impact on spreads. For both shocks a reduction in credit is associated with an increase in unemployment. However, the increase under the SELIC rate shock is twice as large as under the reserve requirement policy

shock.

Table 3 reports the forecast error variance decomposition for interest and reserve requirement shocks, that is, the percentage of the variance of the k -step-ahead forecast error that can be explained by the two shocks. Note that forecast error variance decompositions indicate the importance of random policy shocks, but do not allow any statements about the importance of systematic policy. Investigating the response of other macroeconomic variables to policy shocks allow to improve our knowledge of the transmission mechanism of the two policy instruments, even if the contribution of random policy to overall fluctuations is small.

Interest rate policy shocks are more important for unemployment and price level fluctuations. At a two year horizon, interest rate shocks explain up to 14% and 5% of the fluctuations in prices and unemployment, while the maximum contribution of reserve requirement shocks amounts to about 5% and 3%. By contrast reserve requirement shocks are more important for fluctuations in loans and credit spreads. They explain 14% and 10% at long horizons, compared to 10% and 3% of fluctuations driven by interest rate policy.

Reserve requirement shocks explain about 40% of the fluctuations in reserve requirements at long horizons. Interest rate shocks explain little of the variation in reserve requirements. Taken together, less than 60% of the variation in reserve requirements can be explained as a response to other macroeconomic, non-policy, shocks. The result is consistent with our discussion in Section 3, where we point out that reserve requirements serve various purposes. The part of reserve requirement policy that cannot be explained by macroeconomic fundamentals shows up in our model as a reserve requirement shock. Interest rate shocks explain around 20% of the variation in the SELIC rate, whereas reserve requirement shocks explain only about 2%. The finding implies that about four fifth of unexpected movements in interest rates can be explained by the endogenous response to other macroeconomic shocks.

6 Robustness and Diagnostic Checks

In this section we investigate to what extent the previous results are robust to different measures of prices, real activity and central bank liquidity, instabilities due to different inflation targets possible subsample instabilities, and the role of omitted variables.

6.1 Different Measures for the Prices Indices

The first subplot in Figure 4 shows the results for different price measures. Next to our base measure, the CPI, we plot the responses of the core CPI, the Wholesale Price Index, Producer Price Index and the General Price Index.²³

²³The General Price Index is a weighted average of the Consumer Price Index, the Wholesale Price Index and the Construction Cost Price Index.

Table 3: Forecast Error Variance Decomposition

Horizon	4	12	24	4	12	24
	SELIC Shock			RR Shock		
NEER	5.2	6.1	5.6	5.8	5.7	4.1
Loans	8.2	7.9	9.4	11.9	13.2	13.8
Res	9.7	10.1	11.0	26.7	24.6	23.2
RR	1.8	2.1	1.6	42.3	39.3	37.7
SELIC rate	19.7	17.3	14.8	2.2	1.7	0.6
Spread	3.2	3.5	3.2	8.7	9.4	9.7
CA	2.9	3.9	4.3	5.4	6.3	6.8
CPI	7.2	9.8	13.7	4.1	5.0	5.2
U	3.9	4.6	5.3	2.3	2.9	3.5

Notes: The numbers are in Percent. The numbers in smaller font size are standard errors. The variables are: nominal effective exchange rate (NEER), total aggregate credit (Loans), central bank reserves (CB Res), the SELIC rate, reserve requirements (RR), the interest rate spread between lending and deposit rates (Spread), the ratio of the Current Account (CA) to GDP, the Consumer Price Index CPI and finally the unemployment rate (U).

We focus in our discussion on prices since the results for the other variables are very similar to the baseline case. Each of the price measures shows a positive reaction as a response to the reserve requirement hike. The magnitude of the core CPI response is comparable to the one of the overall CPI. The responses of the other three price measures are stronger. The stronger reaction is in line with the intuition that intermediate goods are less sticky and have a higher exchange rate pass-through.

6.2 Different Measures for Real Activity

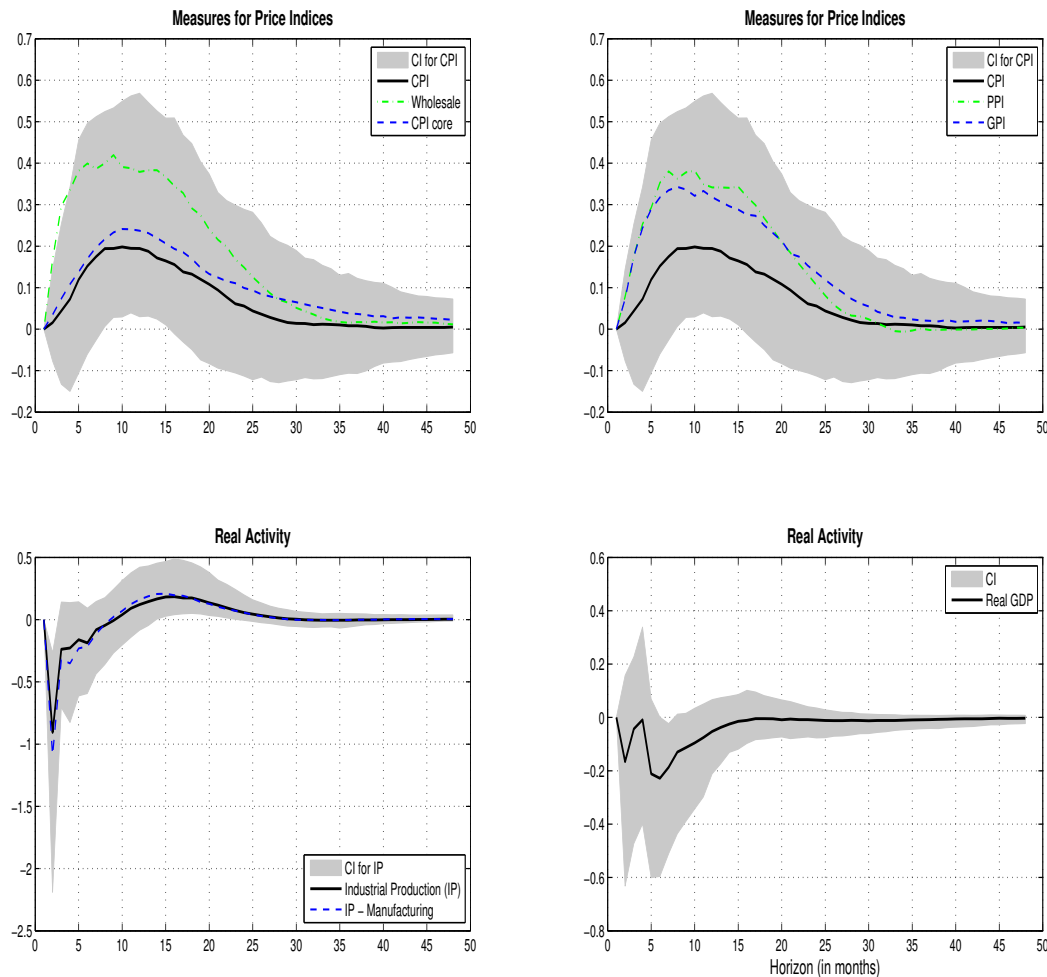
We substitute the unemployment rate by other measures of economic activity. Figure 4 shows the impulse response functions to a reserve requirement shock, when we use the General Industrial Production Index, the Industrial Production Index for the Manufacturing sector, and real GDP²⁴ as measure for economic activity.

For all three measures, we can again observe a contraction in overall economic activity. For the industrial production indices the fall is rather short-lived, but statistically significant. With the real GDP measure the fall is persistent and the impulse response function reaches its trough after about half a year. Results for the other variables are again similar to the baseline case for all three specifications (not shown).

²⁴Since there is no measure for real GDP on a monthly frequency available, we use nominal GDP in domestic currency units deflated by the CPI instead.

Figure 4: Price Indices and Real Activity

The figure reports the impulse response functions for different price indices and various measures for real activity to a surprise innovation in Reserve Requirements. The shock is identified by restricting central bank reserves and reserve requirements to be positive for one quarter. The impulse response functions are shown for a horizon of up to 48 months (4 years).



6.3 Different Measures for Central Bank Liquidity

We proceed by using alternative measures for central bank liquidity. The measure used for the results discussed in section 5 considers the sum of commercial banks' required reserve holdings. The measure is broader than the reserve money component of the monetary base since banks can hold a fraction of their reserve holdings in their own vaults or in remunerated accounts. We consider our baseline measure more appropriate, since it captures the total holdings of official liquidity. As alternative measures for central bank liquidity, we use the reserve money

component of the monetary base, the overall monetary base (including currency and notes), and the extended monetary base.²⁵

Figure 5 shows that the overall results are not affected. Some variables, in particular the current account, the consumer price index, and the nominal effective exchange rate display a somewhat different path, but remain within the confidence bands of the baseline specification.

6.4 Changes in the Inflation Target

Brazil's inflation targeting policy is explicitly announced by means of a point inflation target and a range by the National Monetary Council. As Arestis et al. (2008) and Barbosa-Filho (2007) indicate, the inflation target as well as the range have been continuously adjusted in response to severe macroeconomic shocks. The inflation targeting regime started 1999 with a target value of 8% and a range of 6-10%. As of 2011, the target was at 4.5% with a range of 2.5-6.5%.

A change in the level target will change the intercept of the interest rate policy rule. In order to account for changes in the level of the inflation target, we add separate dummy variables for each change in the target rate to the BVAR model. None of the dummy variables' estimated coefficient is significantly different from zero at the 90% level. The impulse response functions to the two structural shocks also change little (not reported).

A change in the target or the range can also change the aggressiveness of the monetary authority in reacting to inflation, which in turn would affect the response of the economy to policy shocks. Such changes would be reflected in different slope coefficients in addition to different intercepts. The next section will check for sample instability and changes in the transmission mechanism.

6.5 Subsample Instability

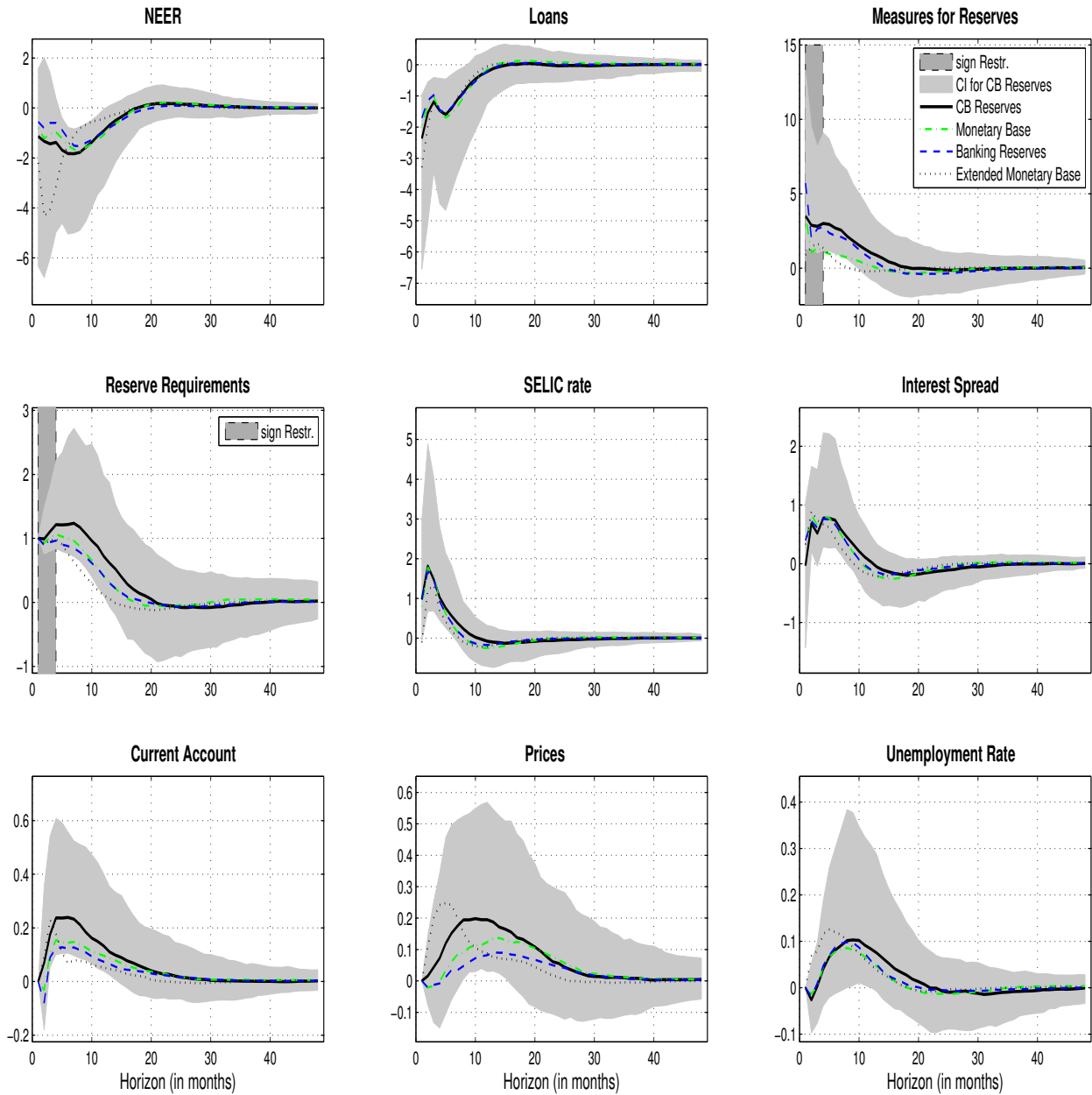
The short period which is covered by our sample does not leave much room for a sophisticated analysis regarding sample instabilities. We proceed by splitting the sample in the middle, hence one period from 1999:7 to 2004:9 and another one from 2004:10 to 2010:12. Each subsample is now characterized by one recession episode as well as by a period of normal economic fluctuations.

The findings from section 5 do not change. For both subsamples the structural impulse response functions to the two monetary policy shocks follow those in Figure 2 and 3 closely. Due to the small sample size, the degree of uncertainty is larger, but most responses remain significant (see appendix).

²⁵The extended monetary base includes additionally mandatory cash deposits and custody positions in central bank and National Treasury securities. Brazilian authorities consider the extended monetary base more relevant than the narrow monetary base when assessing price stability, "as they more accurately reflect the capacity for substitution between money, narrowly defined, and other financial assets" (see http://www.bcb.gov.br/pec/sdds/ingl/ctasanal_autmon_i.htm)

Figure 5: Central Bank Reserves

The figure reports the impulse response functions to a surprise innovation in Reserve Requirements. The shock is identified by restricting central bank reserves and reserve requirements to be positive for one quarter as displayed graphically by the dark grey areas. The impulse response functions are shown for a horizon of up to 48 months (4 years) for various different measures of Central Bank Reserves.



6.6 Omitted Variables

Separate Ljung-Box tests on each residual time series cannot reject the null that they follow a white noise process. However, it is still possible that omitted variables matter for the results. To check whether the two identified monetary policy shocks are correlated with other variables we follow Canova et al. (2009) and compute correlations of the estimated structural disturbances with variables that a large class of general equilibrium models suggests as being jointly generated by various shocks.

Specifically, we compute correlations up to six leads and lags between the shocks and the growth rate of the Brazilian stock market index (BVSP), the oil price²⁶, the policy interest rates of the Bank of Japan, the ECB and the Bank of England.

The cross-correlations indicate that none of the omitted variables correlates significantly with the two structural shocks' disturbances.²⁷

7 Conclusion

The aim of the present paper was to identify the macroeconomic consequences of changes in reserve requirements when the central bank additionally sets the interest rate. We take the example of Brazil, where we have both a homogeneous monetary policy framework and sufficient variation in reserve requirements. Based on a structural vector autoregressive model, we find that a discretionary increase in reserve requirements leads to a contraction in domestic credit. Moreover, the tightening leads to increases in unemployment, an exchange rate depreciation, a current account surplus, and increases in the price level. Regarding interest rate policy, our results are in line with standard economic theory. Positive interest rate surprises coincide with a contraction in credit, an exchange rate appreciation, increases in unemployment, and a decline in inflation. The results are therefore in line with arguments that ascribe interest rate policy an important role to control price fluctuations, but also with arguments that emphasize the dilemma monetary policy faces when dealing with capital inflows (IMF, 2007). Our results indicate that reserve requirements provide a potential way to curb credit growth without attracting net capital inflows and appreciating the exchange rate. It is, however, doubtful whether reserve requirements are an appropriate tool to achieve price stability under an interest rate policy framework. In that sense, reserve requirement policy can serve as a complement to interest rate policy for financial stability considerations, but cannot be its substitute with regards to a price stability objective. We have studied the effects of reserve requirement changes when the central bank simultaneously sets the interest rate through open market operations. We expect substantially different effects

²⁶We use the cyclical component of the oil price only for checking a possible correlation with the structural disturbances. For this we apply the Hodrick-Prescott filter on the logarithm of the oil price.

²⁷The statistical importance of the cross-correlations has been judged by means of the upper and lower limits of an asymptotic 95% confidence tunnel for the null hypothesis of no cross-correlation.

under other central bank policy frameworks, for example, if reserve requirements are used to achieve a pre-specified money growth target. Our analysis has also focused on the short term effects of reserve requirement changes. The effect of higher reserve requirement levels on the costs of financial intermediation and long term growth prospects is another important aspect that policy makers need to consider.

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A Data

The data being used are monthly Brazilian data over the period 1999M7:2010M12. The series were taken from the OECD database, from the IFS (International Financial Statistics) database, from the World Bank (WB), from the Fundação Getulio Vargas (FGV) and from the Banco Central do Brasil (BCdB) under the following www-link: <https://www3.bcb.gov.br/sgspub/localizarserieslocalizarSeries.do?method=prepararTelaLocalizarSeries>. Table 4 specifies the details.

Table 4: Data: Definitions and Sources

		Description	Source	Coding
1	CPI	National Consumer Price Index	IFS	223"64"M
2	i_L	Lending Rate	IFS	223"60P"M
3	NEER	Nominal Effective Exchange Rate	IFS	223"__NEC
4	SELIC	BRA Federal funds rate	BCdB	SELIC
5	i_D	Saving Deposits Rate	IFS	223"60K"M
6	U	Unemployment rate: survey-based (all persons) (SA)	OECD	BRA"UNRTS
7	FFR	USA Federal funds rate	OECD	USA"IRSTF
8	SRR	Statutory Reserve Requirements and additional Requirements (<i>exigibilidade adicional</i>) on Sight, Time and Saving Deposits	BCdB	.
9	RMP	World Raw Materials Price Index	WB	RMPIdx
10	RR	Financial institutions reserve requirements - Total balance	BCdB	17633
11	D	Saving Deposits, Time Deposits, Sight Deposits, Value, EoP	BCdB	.
12	L	Domestic Credit	IFS	223"32"M
13	MB	Monetary Base (EoP)	BCdB	1788
14	BR	Banking Reserves (EoP)	BCdB	1787
15	EMB	Extended Monetary Base (EoP)	BCdB	1833
16	PPI	Producer Price Index	FGV	200053
17	WhPI	Wholesale Price Index (IPA)	BCdB	225
18	CPIcore	Consumer Price Index core (IPCA - core) - Exclusion measure of core	BCdB	4467
19	GPI	General Price Index Domestic Supply (IGP-10: Índice Geral de Preços - 10)	FGV	209433
20	GDP	Gross Domestic Product (GDP) - monthly, current prices	BCdB	4380
21	GDP\$	Gross Domestic Product (GDP) - monthly, in US Dollars	BCdB	4385
22	IP	General Industrial Production Index	BCdB	11064
23	IPM	Industrial Production Index - Manufacturing	BCdB	11066

Notes: SA refers to *Seasonally Adjusted* and EoP to *End of Period*.

B Additional Figures

Figure 6: Reserve Requirement Shock

The figure reports the impulse response functions to a surprise innovation in reserve requirements based on the subsample which ranges from 1999:7 to 2004:9.

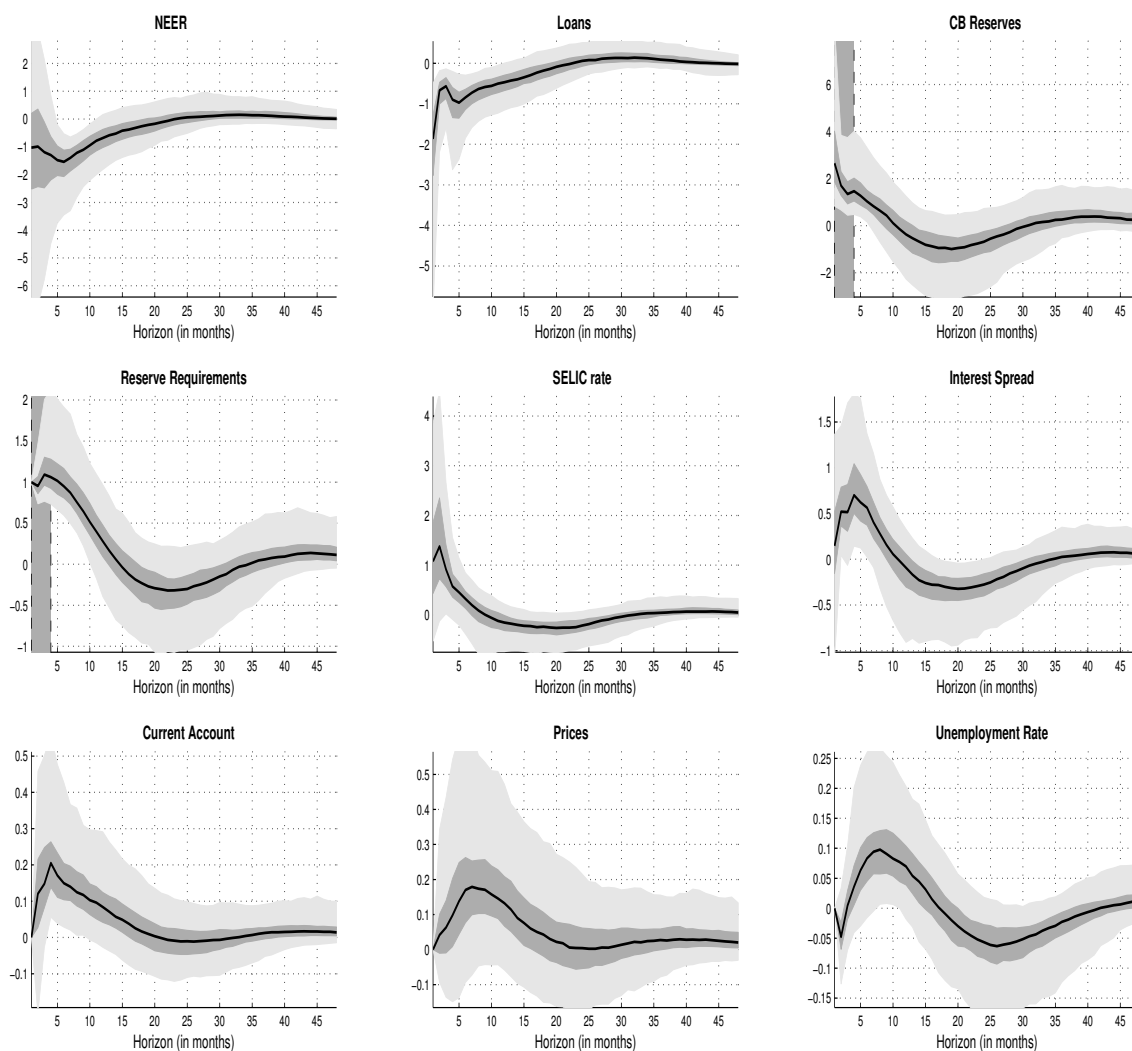
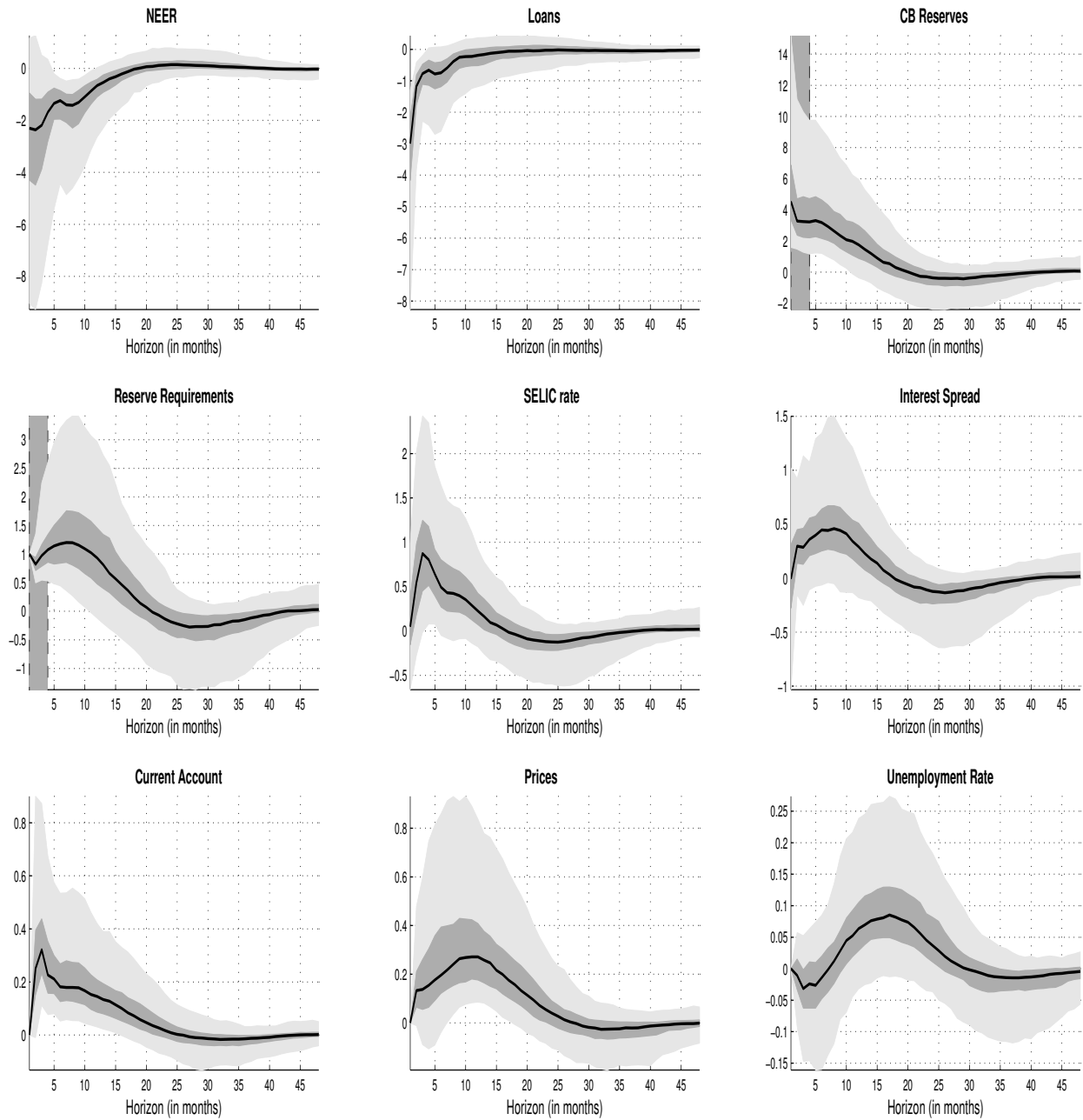


Figure 7: Reserve Requirement Shock

The figure reports the impulse response functions to a surprise innovation in reserve requirements based on the subsample which ranges from 2004:10 to 2010:12.



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