The Dynamic Effects of Interest Rates and Reserve Requirements*

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Abstract

This paper quantifies the dynamic macroeconomic effects derived from both; shocks to conventional monetary policy and shocks to reserve requirement ratios applied to deposits held at commercial banks in Peru. The analysis tackles reserve requirements on domestic as well as foreign-currency deposits. Structural Vector Autoregressive (SVAR) models are identified through a mixture of zero and sign restrictions for the period 1995-2013. Contractionary monetary policy shocks generate a negative effect on aggregate bank loans and a positive effect on loan-deposit interest rate spreads. Most importantly, shocks to the two reserve requirement ratios produce a negative effect on aggregate credit in their corresponding currencies and a mild effect on both aggregate real economic activity and the price level. We consider possible mechanisms that may help explain the dynamic effects uncovered in the paper.

JEL Classification: E43, E51, E52
Key words: Monetary Policy, Interest Rates, Reserve Requirements, Sign Restrictions

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1 Introduction

Since the outbreak of the 2007-2008 global financial crisis, monetary policies in developed and emerging economies rely more on unconventional policies to achieve macroeconomic and financial stability. Reserve requirement ratios are examples of such type of policies used by a number of emerging market countries (see Montoro and Moreno, 2011; Tovar *et al.*, 2012; Cordella *et al.*, 2014, among others). Even though reserve requirements have been abandoned in most developed economies, they have been actively used in the emerging world, especially after the global financial crisis. This has been the case for example in Colombia, Brazil, Peru or Turkey.

This paper studies the special case of Peru, where the central bank makes active use of reserve requirement policies applied to both domestic and foreign currency banking liabilities (Rossini *et al.*, 2014; Choy and Chang, 2014). The paper explores the transmission mechanisms of conventional interest rate policy together with that of reserve requirement policies in both currencies. It is important to remark that this paper assesses the dynamic effects derived from orthogonal shocks. It is not the purpose of this paper to characterize the systematic component of monetary policy or to provide a justification for the use of each policy instrument at a given point in time. In other words, our analysis is more positive than normative.

Reserve requirement ratios are part of the pool of instruments that the central bank uses to implement its policy. Since the adoption of the Inflation Targeting regime in 2002, the central bank implements its policy by setting a reference interbank interest rate and uses open market operations to keep the interbank rate at the reference level (Rossini and Vega, 2007), given reserve requirement rates [1]. Nevertheless, due to the 2008 global financial turmoil, the central bank started using reserve requirement

[1] The central bank adopted the Inflation Targeting regime in 2002. Later in September 2003, the central bank set the interbank rate in domestic currency (Nuevo Sol or PEN) as the target instrument. Previously, since early 2001, the central bank had started setting a corridor for interest rates.

policies actively in both domestic and foreign currency for monetary control purposes, specially to fight undue credit growth dynamics related to capital inflows associated to unprecedented expansionary monetary policies in the USA. It is important to recall however that reserve requirements were used for implementing monetary policy even in the period previous to IT (see Montoro and Moreno, 2011; Armas *et al.*, 2014), however the instrument was used only sporadically.

The rationale behind the use of reserve requirements lies on the existence of an externality whereby banks issue too much short-term debt (deposits) that fund excessive money creation (loans). Banks do not completely internalize the fire-sale costs generated when a system-wide liquidity shock hits (Stein, 2012). Armas *et al.* (2014) examines the case for reserve requirements when the dollarization of the financial system is high.

On the other hand, there are two competing theories of how reserve requirement shocks affect credit levels as well as deposit and lending interest rates. The first theory posits that reserve requirements shocks first affect loanable funds (deposits) and prompts banks to change their lending levels. DSGE models like Glocker and Towbin (2012b) and Carrera and Vega (2012) have this money-multiplier property built in their structure. The second theory asserts that banks decide first on their lending levels and this urges them to create deposits (Disyatat, 2011; Bianchi and Bigio, 2013). In this case, changes in reserve requirements affect the riskiness of banks balance sheet that in turn affect lending levels. On a similar vein, Alper *et al.* (2014) posits that changes in the asset portfolio due to reserve requirement changes affect the liquidity risk of banks which prompts banks to adjust their lending and interest rate levels.

This paper identifies both; interest rate and reserve requirement shocks in a unified framework. The method relies on imposing a mix of zero and sign restrictions in a structural vector autoregressive (SVAR) model for the Peruvian economy. The restrictions are based on the conventional wisdom about the main characteristics of the aforementioned shocks. For instance, policy interest rate shocks are identified according to restrictions implied in Rossini and Vega (2007), while reserve requirement shocks are identified following León and Quispe (2011) and Armas *et al.* (2014). In all cases, we remain agnostic about the effects of policy on credit levels.

Robust zero and sign restrictions in SVARs have been used in a number of applications (see Arias *et al.*, 2014, and references therein), in particular, to identify the effects of monetary policy shocks[2]. This paper aims to identify two types of policy shocks by following the algorithms presented in Rubio-Ramírez *et al.* (2010) and Arias *et al.* (2014).

The sign restrictions approach does not identify one structural model. The identification is partial as we are only interested on the effects of two types of shocks. In fact, a set of plausible structural models support the sign restrictions. Therefore we cannot know which of the aforementioned theoretical models performs bests in fitting the data. Our results are meant to be a guide for structural model building and for policy making.

As far as we know, the only other paper that identifies interest rate as well as reserve requirement shocks is Glocker and Towbin (2012a). This latter paper also uses a mix of zero and sign restrictions in a SVAR setup. Our paper differs from Glocker and Towbin (2012a) in two ways. First, the sign and zero restrictions diverge. In our setup, a surprise hike in reserve requirements increases the loan-deposit interest rate spread while they only impose a zero effect within a month. The second difference is that they apply their method to Brazil while we apply it to Peru, which features a highly dollarized financial system. Therefore, we also include an additional model where we measure the effect of shocks to reserve requirements to dollar-denominated

[2] See for example Faust (1998), Canova and De Nicoló (2002) and Uhlig (2005).

bank deposits.

The main findings of the paper are as follows: i) standard interest rate policy shocks can be found in Peruvian data as described by Rossini and Vega (2007), i.e. a tight monetary policy generates an appreciation of the domestic currency and a fall in both output and prices. These shocks are also useful for controlling credit levels in both domestic and foreign currency, and we also find evidence of a rise in interest rates spreads between loan and deposit rates, ii) a rise in reserve requirements rates in both currencies can significantly reduce the level of aggregate credit. Our results are in line with other empirical studies such as Tovar *et al.* (2012), Glocker and Towbin (2012a) and Armas *et al.* (2014) and also with theoretical approaches such as Betancourt and Vargas (2009), Carrera and Vega (2012) and Glocker and Towbin (2012b).

The paper is organized as follows: section 2 presents some empirical evidence on the effects of monetary policy in Peru, section 3 lays out the model, section 4 describes the identification procedure, section 5 shows the estimation procedure, section 6 discusses the main results, section 7 presents further extensions and section 8 concludes.

2 Empirical evidence of monetary policy in Peru

The central bank had implemented monetary policy by using money aggregates until the adoption of Inflation Targeting in 2002, when it started using the interbank interest rate as its operational target (Rossini and Vega, 2007). Before 2002, reserve requirements and money aggregates were crucial for explaining the inflation rate process, and so they were actively used as policy instruments. It is only during and after the global financial crisis that reserve requirements were actively used again (León and Quispe, 2011).

The effects of monetary policy shocks in Peru identified through interest rates changes have been measured using structural VARs in various papers: Winkelried (2004); Bigio and Salas (2006); Castillo *et al.* (2010); Lahura (2010). Table 1 summarizes these results. On average, an interest rate shock produces a maximum effect on output within the first year of the shock and a maximum effect over prices between one and two years of the shock. Though the magnitud of the effects vary across studies, the results are compatible with well-known effects of monetary policy shocks.

The effects of reserve requirements have been less studied. No paper has identified reserve requirement shocks for Peru so far. However, two related papers study effects of reserve requirements ratios on credit and interest rates in Peru. First, Dancourt (2012) estimates a dynamic panel data model to find the sensitivity of credit levels at banks and smaller financial institutions to reserve requirement ratios and policy interest rates. According to Dancourt (2012), bank credit depends negatively on both measures of monetary policy. The second paper that measures the effects of reserve requirements for Peru is Armas *et al.* (2014). The paper evaluates the sequence of reserve requirement tightenings occurred during 2010 over credit and interest rate levels by using the counterfactual policy evaluation analysis of Pesaran and Smith (2014) and broadly finds that the policy tightening produced negative effects on credit levels relative to the no-policy counterfactual, a positive effect on lending rates and a negative effects on deposit rates. In essence, the paper finds that hikes in reserve requirements are linked to increases in bank interest rate spreads.

Table 1. *Empirical evidence of interest rate shocks in Peru (Lahura, 2012)*

Articles	Shock size	Maximum effect over prices		Maximum effect over output		Data Frequency	Sample
		Magnitud	Months	Magnitud	Meses		
Lahura (2012)	25 bp	0.40	14	1.50	9	Monthly	2003-2011
Castillo et.al (2011)	100 bp	1.00	29	0.40	41	Monthly	1995-2009
Lahura (2010)	1 s.d.	0.23	6	0.16	7	Monthly	1995-2005
Bigio and Salas (2006)	100 bp					Monthly	1994-2004
* expansion		0.50	16	0.50	10		
* recession		0.25	16	1.00	10		
Winkelried (2004)	100 bp	0.20	12	0.50	12	Monthly	1993-2003
Salas (2011) (a)	150 pbs.	0.40	12	0.30	9	Quarterly	2001-2008
Vega et al. (2009)	100 pbs.	0.15	18	0.1	9	Quarterly	1999-2006
Castillo et al. (2009)	100 pbs.					Quarterly	1994-2007
* without dollarization		0.15	12	0.38	9		
* with dollarization		0.24	15	0.32	9		
Rossini and Vega (2007)	100 pbs.					Quarterly	1994-2007
* without intervention		0.08	15	0.10	12		
* with intervention		0.15	24	0.09	12		
* without balance sheet effect		0.20	30	0.20	24		
* with balance sheet effect		0.08	15	0.10	12		

(a) The effect is over output and core inflation.

3 The SVAR Model

Consider the SVAR model

$$\mathbf{y}_t'\mathbf{A}_0 = \sum_{i=1}^{p} \mathbf{y}_{t-i}'\mathbf{A}_i + \mathbf{c} + \mathbf{w}_t'\mathbf{D} + \varepsilon_t' \text{ for } t = 1, \dots, T \tag{1}$$

where $\mathbf{y}_t$ is a $n \times 1$ vector of endogenous variables, ε_t is a $n \times 1$ vector of structural shocks such that $\varepsilon_t \sim N(0, I_n)$, $\mathbf{A}_i$ is a $n \times n$ matrix of structural parameters for $i = 0, \dots, p$, $\mathbf{c}$ is a $1 \times n$ vector of structural parameters, $\mathbf{w}_t$ is a $r \times 1$ vector of exogenous variables, $\mathbf{D}$ is a $r \times n$ matrix of structural parameters, p is the lag length and T is the sample size.

The SVAR of order p can be written in a more compact form as

$$\mathbf{y}_t'\mathbf{A}_0 = \mathbf{x}_t'\mathbf{A}_+ + \varepsilon_t' \text{ for } t = 1, \dots, T \tag{2}$$

where

$$\mathbf{A}_+' \equiv \begin{bmatrix} \mathbf{A}_1' & \cdots & \mathbf{A}_p' & \mathbf{c}' & \mathbf{D}' \end{bmatrix}, \mathbf{x}_t' \equiv \begin{bmatrix} \mathbf{y}_{t-1}' & \cdots & \mathbf{y}_{t-p}' & 1 & \mathbf{w}_t' \end{bmatrix}$$

The model is structural, since ε_t is a vector of orthogonalized shocks. In turn, the reduced form of this model is given by:

$$\mathbf{y}_t' = \mathbf{x}_t'\mathbf{B} + \mathbf{u}_t' \text{ for } t = 1, \dots, T \tag{3}$$

where $\mathbf{B} \equiv \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t' \equiv \varepsilon_t'\mathbf{A}_0^{-1}$, and $E[\mathbf{u}_t\mathbf{u}_t'] = \Sigma = \left(\mathbf{A}_0\mathbf{A}_0'\right)^{-1}$. That is, the procedure of structural identification establishes a mapping between the reduced form parameters $(\mathbf{B}, \Sigma)$ and the structural ones $(\mathbf{A}_+, \mathbf{A}_0)$. The latter task can be simplified to find a matrix $\mathbf{A}_0$. However, there is a large literature that discusses different ways to achieve it (see for instance Canova, 2007; Rubio-Ramírez *et al.*, 2010; Kilian, 2011).

Once the model is identified, we can construct impulse-response function (IRFs).

Basically, the IRF is a $n \times n$ matrix that contains the dynamic responses of the full vector $\mathbf{y}_{t+h}$ after a structural innovation ε_t that happened h periods ago. We can then collect these responses and compute the cumulative impacts, so that:

$$f(\mathbf{A}_0, \mathbf{A}_+) = \begin{bmatrix} \mathbf{L}_0(\mathbf{A}_0, \mathbf{A}_+) \\ \vdots \\ \mathbf{L}_h(\mathbf{A}_0, \mathbf{A}_+) \\ \vdots \\ \mathbf{L}_\infty(\mathbf{A}_0, \mathbf{A}_+) \end{bmatrix}$$

where $\mathbf{L}_h(\mathbf{A}_0, \mathbf{A}_+) = \left(\mathbf{A}_0^{-1}\mathbf{J}'\mathbf{F}^h\mathbf{J}\right)'$, with $\mathbf{F}$ being the companion form matrix and $\mathbf{J}$ a selection matrix (see appendix B for details).

4 Identification

To identify the structural shocks, we impose two sets of restrictions. The first group is related to zero restrictions in the contemporaneous coefficients matrix, as in the old literature of Structural VARs (Sims, 1986). The second group comprises a set of sign restrictions as in Canova and De Nicoló (2002), where we fix a horizon of three months, i.e. the shock occurs in period 0, and we set the sign restrictions for periods 0, 1 and 2. Moreover, this set of restrictions can be re-arranged so that it is clear what we impose for the contemporaneous reaction of variables and for the lags. These identifying restrictions are displayed in Table 2.

Restrictions for INT shocks (conventional monetary policy) are standard in the literature and reflect the pattern expected in a structural dynamic model. In this regard, Canova and Paustian (2011) argue that sign restrictions are robust to parameter and specification uncertainty. We extend the latter for the Peruvian case following the

Table 2. *Zero and sign restrictions about the effects of monetary policy shocks on macroeconomic variables*

Variables	INT shock		RR shock	
	$t=0$	$t=1,2$	$t=0$	$t=1,2$
Amount of reserves	?	?	$\geqslant 0$	$\geqslant 0$
Exchange rate	$\leqslant 0$	$\leqslant 0$	?	?
Interbank rate	$\geqslant 0$	$\geqslant 0$	?	?
Reserve ratio	?	?	$\geqslant 0$	$\geqslant 0$
Credit level	0	?	0	?
Credit level (USD)	0	?	0	?
Interest rate spread	0	?	$\geqslant 0$	$\geqslant 0$
Price level	0	$\leqslant 0$	0	?
Real product	0	$\leqslant 0$	0	?

Note: INT shocks are policy interest rate shocks while RR shocks are reserve requirement shocks. Time t is measured in months and the question mark **?** means that we remain agnostic.

mechanism described in Rossini and Vega (2007) and in Vega *et al.* (2009). That is, a standard monetary policy shock produces an increase in the interest rate (INT), a fall in output and prices and an appreciation of the domestic currency, reflected in a fall in the nominal exchange rate [3].

This type of identification is robust to the specific instrument the central bank uses to affect interest rates. Before the central bank implemented inflation targeting, it controlled narrow monetary aggregates such as base money or current account deposits held by comercial banks at the Central Bank. A contractionary monetary policy shock in this case produces the same effect as a positive interest shock. A contractionary monetary policy shock in the era of money aggregates is also compatible with a fall in bank reserves at the time of the shock but we do not impose this restriction and let the data uncover this effect. Therefore, to identify standard monetary policy shocks, we do not need to restrict the sample only to the inflation targeting period.

[3]Unlike Glocker and Towbin (2012a), we identify INT shocks by restricting output , prices and the exchange rate, and we do not restrict the amount of reserves.

Regarding reserve requirement (RR) shocks, we impose that a contractionary shock generates a positive response of reserves and a positive effect on interest rate spreads. The effect on spreads are due to the fact that in the short run, banks quickly change their interest rates rather than adjust quantities. The positive effect on spreads is consistent with general evidence of faster responses of loan interest rates than deposit ones (Lahura, 2005; León and Quispe, 2011), and it is also based on theoretical models that link reserve requirements with interest rates such as Betancourt and Vargas (2009), Carrera and Vega (2012) and Glocker and Towbin (2012b). Furthermore we set, following Glocker and Towbin (2012a), zero restrictions to the variables that do not react instantaneously to the structural policy shocks, i.e. the so-called *slow* variables.

Again, these restrictions are also robust to the monetary policy framework in place before and after inflation targeting. For example, as early as Reinhart and Reinhart (1999) and references therein, the link between reserve requirements and interest rates spreads are suggested to be of the sorts we impose as restrictions.

5 Estimation

Estimation is performed in two steps. First, the reduced form of the model (3) is estimated through Ordinary Least Squares (OLS), so that the output is $(\mathbf{B}, \Sigma)$. In the second step, we use the estimation output as the posterior mean, and we take draws from this distribution as it is described in the following estimation algorithm:

1. Set $K = 2000$ and $k = 0$.

2. Draw $\left(\mathbf{B}^k, \Sigma^k\right)$ from the posterior distribution.

3. Denote $\mathbf{T}^k$ such that $(\mathbf{A}_0, \mathbf{A}_+) = \left((\mathbf{T}^k)^{-1}, \mathbf{B}^k(\mathbf{T}^k)^{-1}\right)$ and draw an orthogonal matrix $\mathbf{Q}^k$ such that $(\mathbf{T}^k)^{-1}\mathbf{Q}^k, \mathbf{B}^k(\mathbf{T}^k)^{-1}\mathbf{Q}^k$ satisfy the zero restrictions (see appendix B.

4. If sign restrictions are satisfied, keep the draw and set $k = k + 1$. If not, discard the draw and go to Step 5.

5. If $k < K$ return to Step 2, otherwise stop.

It is worth to remark that in the step 2 we do the following[4]:

- Draw Σ^k using an Inverse-Wishart distribution.

- Draw $\mathbf{B}^k$ from a Normal distribution conditional on Σ^k.

Furthermore, the matrix $\mathbf{Q}^k$ is orthogonal, which means that $(\mathbf{T}^k)^{-1}\mathbf{Q}^k$ is a rotation of $(\mathbf{T}^k)^{-1}$. Strictly speaking, we keep the reduced form rotations that satisfy both the zero and the sign restrictions. See also appendix B for further details. Last but not least, in this paper we perform Bayesian inference. That is, we collect the accepted draws and compute the associated percentiles in order to pin down the confidence intervals. On the other hand, there are methods for computing classical confidence intervals in partially identified models; the interested reader is referred to Moon *et al.* (2011) and Moon and Schorfheide (2012).

6 Results

6.1 Effects of interest rate shocks:

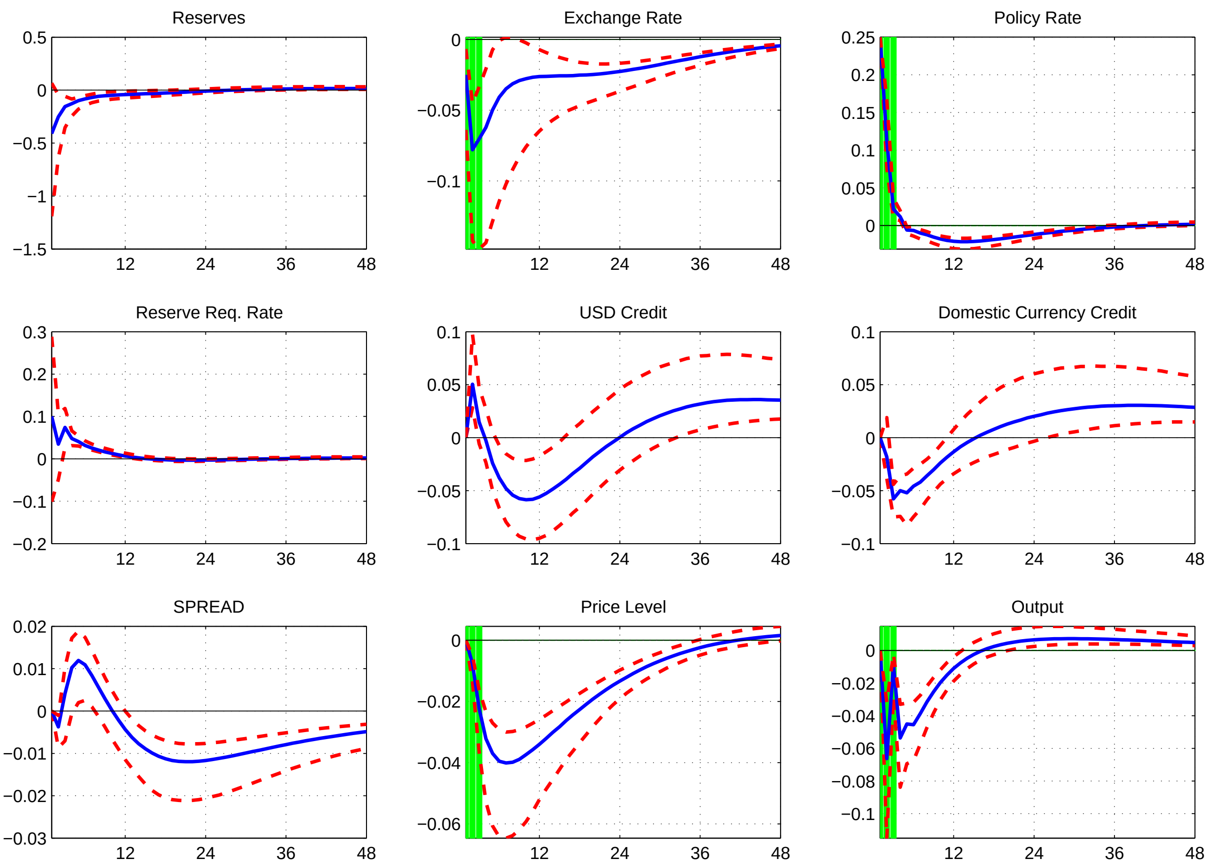
Figure 1 depicts the effect of a policy shock that produces a 0.25% rise in the interest rate (INT). The identifying restrictions allow the data to generate effects that are standard in the literature, i.e. an appreciation of the domestic currency, a decrease in economic activity and the price level. Indeed, besides the shaded areas that indicate the sign restrictions, an increase in INT generates a surge in interest rate spreads,

[4] This step is similar to Glocker and Towbin (2012a). In particular, draws of reduced form coefficients can be done equation by equation.

namely, a short-run stronger increase in loan interest rates than in deposit interest rates (Lahura, 2005). At the same time we observe a fall in banking reserves associated with a traditional liquidity effect of an interest rate rise. The impact effect on the reserve ratio is positive, however this puzzling result is not statistically significant. In fact, the uncertainty about the reserve ratio on impact is very wide.

Credit levels statistically decrease in both currencies within the first year. The fall in output goes hand in hand with the fall in credit levels. This may be due to a standard bank lending channel of monetary policy which affect the credit supply negatively or to the aggregate downward demand pull on credit.

Figure 1. *Effects of a 0.25% interest rate shock; median value and 66% bands*



6.2 Effects of reserve requirement shocks

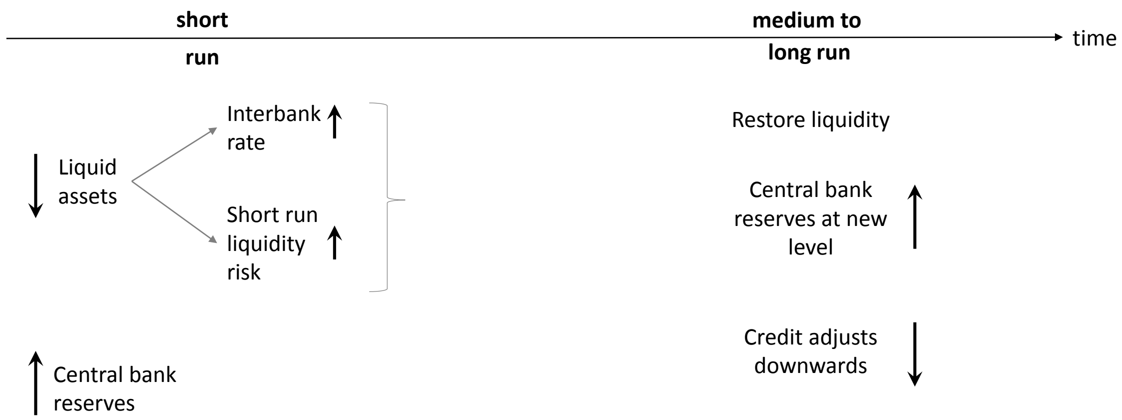
To better understand the dynamic effects of reserve requirements we use the diagram depicted in Figure 2. When there is a surprise increase in reserve requirements, suddenly banks realize that they have to accumulate more reserves in the form of cash or current account deposits at the central bank[5]. This forces banks to liquidate some assets because there is no other way of adjustment in the short run when credit levels or the composition of funding remains fixed.

More short run demand for central bank liquidity prompts the interbank rate to increase and, more importantly, the sale of liquid assets induces more idiosyncratic funding liquidity risk in the short run. To avoid confusion, we use the term total liquidity to denote required central bank reserves and liquid assets. Reserve requirements serve as a buffer stock of liquidity that the central bank can ease when an aggregate shock hits. Liquid assets serve to face bank idiosyncratic funding liquidity shocks.

In the medium to long run, banks can adjust their overall asset portfolio by reducing credit. Namely, the increase in central bank reserves is compensated by a fall in credit while liquid asset levels are restored to its original level. Two forces operate in the months after the shock in terms of the credit level; first, banks increase the loan interest rate, and slightly increase or decrease deposit rates which together produce a fall in loan-deposit spreads and credit levels. This is the interest rate channel. As loanable funds reduce, credit is also hit. This is the standard lending channel. But there is a another force: the liquidity channel. Banks tend to restore their previous liquidity levels after the initial forced reduction. During the restoration period, they still face some liquidity risk. This implies that the opportunity cost of funding by deposits is a bit higher and induces banks to reduce deposits and, in turn, to reduce

[5]Or any other form of assets legally accepted by the central bank to meet the reserve requirement.

Figure 2. *Short and long-run effects of a rise in reserve requirements*



credit levels (se also Alper *et al.*, 2014).

The overall picture is that after a rise in reserves requirements banks change their asset portfolio during the months after the crisis: (i) higher total liquidity comprised by central bank reserves and other liquid assets but (ii) lower credit levels (see also Armas *et al.*, 2014).

However, in a dollarized financial system, i.e. when banks resort to funding in domestic currency as well as in US dollars and hold assets denominated in both currencies, banks have a richer set of options to absorb the shock.

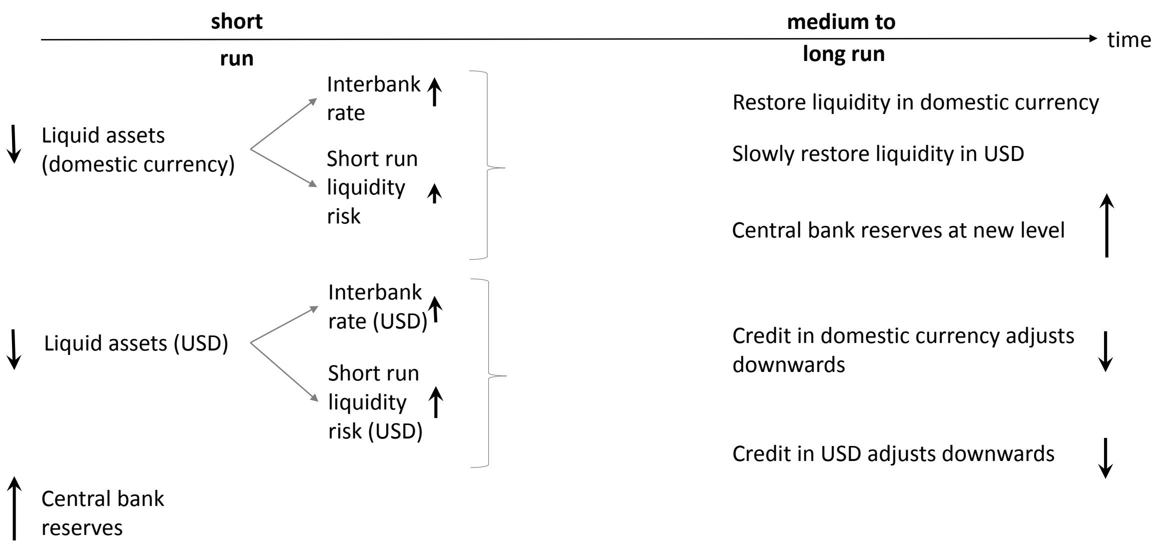
Figure 3 shows that in the short run, banks can now also sell US-dollar assets in exchange of central bank reserves. When banks sell US-dollar liquid assets, they face two sorts of risks: liquidity and market risk.

Market risk appears due to losses in their portfolio stemming from variations in the exchange rate, but as central bank forex intervention can smooth swings in the exchange rate, market risk is reduced. This is known ex-ante by banks, so they put a lower weight on this risk when deciding their sales of US-dollar liquid assets in exchange of central bank reserves in domestic currency.

Liquidity risk is the likely loss incurred by having to borrow reserves at a high cost to face a high US-dollar deposit withdrawals, just when the bank is reducing his level of US-dollar liquid assets.

A key point to note is that banks may not necessarily want to restore all their US-dollar liquidity in the medium term. For a fact, total domestic-currency liquidity needs to be higher given the increase in reserve requirements in domestic currency. Some of this higher liquidity in domestic currency is the result of reducing liquidity in US dollars. There is a degree of swapping in the liquidity portfolio: more domestic currency but less US-dollar assets. In turn, when total domestic-currency liquidity is higher, banks reduce their domestic-currency credit via the standard lending and interest rate channels, however; when the total US-dollar liquidity falls, banks will tend to reduce their risk exposure by reducing US-dollar deposits (via a likely fall in deposit interest rates) which in turn translates into a reduction of US-dollar credit.

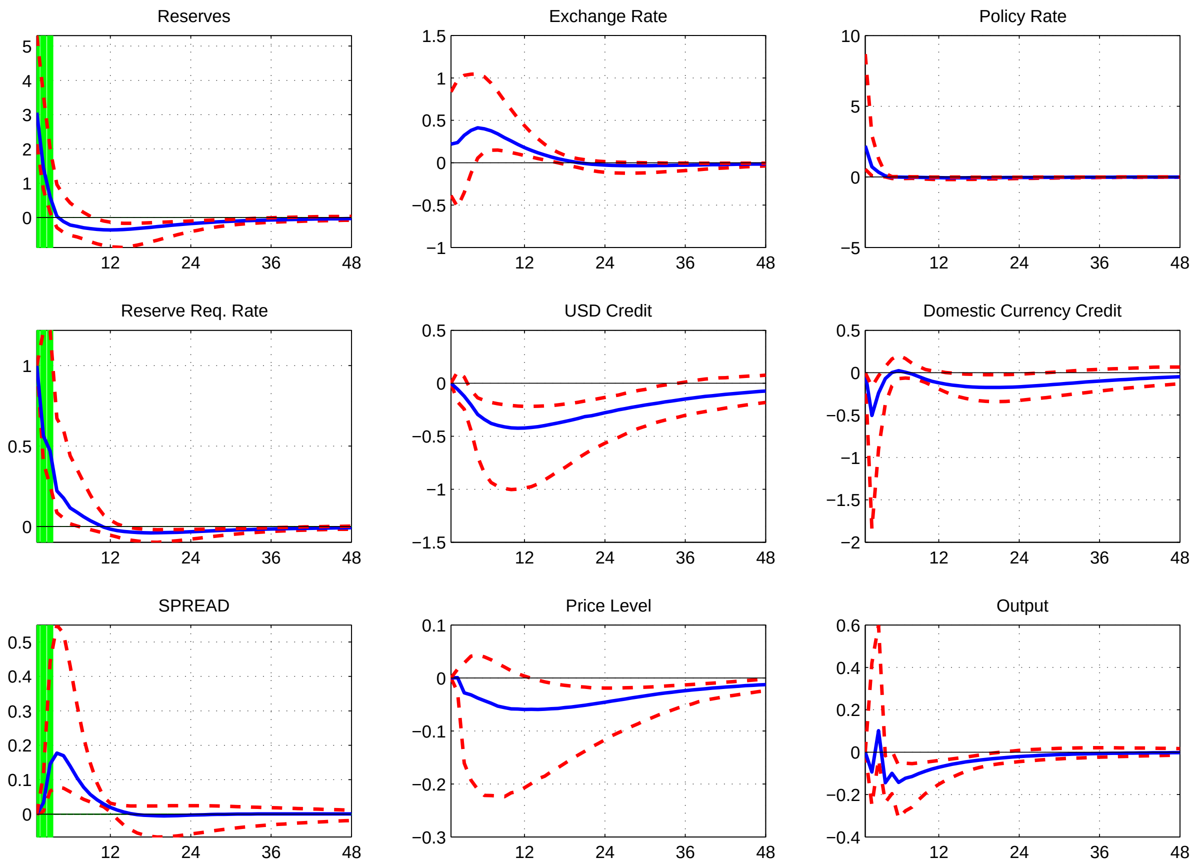
Figure 3. *Effects of a rise in domestic currency reserve requirements under a dollarized financial system*



With the described background in mind, we can now analyze the IRFs due to a 1% shock increase in the RR depicted in Figure 4. The shaded areas are related to the imposed sign restrictions. An increase in RR raises the interbank interest rate though the extent of the effect is uncertain. The mean positive effect is due to the increase in the demand for liquid funds in the interbank market.

Loans granted in both domestic and foreign currency fall. Domestic currency credit falls sharply by 0,5 percent within the first months, thereafter it remains low relative to its normal trend. US-dollar credit also falls but in a more persistent manner. It also achieves a maximum fall of 0,5 percent below its trend but in a about 12 months and thereafter converges slowly to its original level. After three years the impact of the RR shock over the two credit levels essentially vanishes.

Figure 4. *A 1% reserve requirement shock; median value and 66% bands*



The pattern of effects agree to the analysis described in Figure 3 above. It should also be noted that part of the credit reduction may be explained by the downward aggregate demand pull observed in the IRFs. We cannot identify what part of the fall in US-dollar credit is attributable to the liquidity channel described above and what part is related to the fall in aggregate demand.

In fact, prices and real activity fall as expected but the effect is more uncertain than what the conventional interest rate policy shock achieves.

6.3 Relative size of both shocks

Regarding the size effects of the two shocks presented, it seems to be the case that reserve requirements shocks produce larger effects than interest rates ones, especially for output and prices. The reason is that we normalize the interest rate shock to be only 0.25%, whereas reserve requirements shocks are in the order of 1%. For instance, the maximum effect of interest rates and reserve requirements on prices are around 0.04% and 0.06% respectively. In order to get comparable results we should multiply the interest rate effects by 4, so that the maximum effect on prices will be 0.16% > 0.06%. As a result, conventional interest rate shocks are more powerful to affect output and prices.

On the other hand, the maximum effect of interest rates and reserve requirements on credit are around 0.05% and 0.5% respectively. In order to get comparable results we should multiply the interest rate effects by 4, so that the maximum effect on credit will be 0.2% < 0.5%. As a result, reserve requirement shocks are more powerful to affect credit.

We can also perform a deeper analysis to the depicted impulse responses. Regarding interest rate shocks, the maximum impact on credit and output is around 0.05, meaning that the relative reaction (output/credit) is about 1. Moreover, the maximum impact on prices is around 0.04, meaning that the relative reaction (prices/credit) is about 0.8. In a similar fashion, regarding reserve requirement shocks, the maximum impact on credit is 0.5 and for output is around 0.15, meaning that the relative reaction (output/credit) is about 0.3. Moreover, the maximum impact on prices is around

0.05, meaning that the relative reaction (prices/credit) is about 0.1. All in all these results implies that, if anything, interest rates are more powerful affecting output and prices, whereas reserve requirements are more powerful affecting aggregate credit.

Our results are also in line with Glocker and Towbin (2012a), with the exception of the response of prices after a reserve requirements shock. Here we have a negative response, whereas the mentioned paper has a positive one.

7 Extension: Foreign Currency Reserve Requirements

Our setup can be easily extended to study the role of foreign currency reserve requirements. The decade following the emerging market crisis at the onset of the twenty first century, witnessed the inflows of large amounts of capitals to these economies. In this context, the use of foreign currency reserve requirements as a macro-prudential tool became highly popular in emerging economies such as Peru (see Reinhart and Reinhart, 2008; Hoffmann and Loeffler, 2014, among others).

To identify the effects of foreign currency reserve requirement shocks, we need to include more variables in the SVAR model, since the current information set is not suitable to study this case. First, we include the amount of reserves and the reserve requirement rates in US dollars[6], we also include the interest rates spreads in foreign currency and finally, we include the amount of Net International Reserves (NIR). Nevertheless, the data availability is limited for reserve requirements in this currency to dates departing from 2001. Therefore, we restrict the full sample to the period (2001:12-2013:11).

Identifying restrictions of this new model are displayed in Table 3. We adopt a similar scheme than the one considered for domestic currency: The foreign currency

[6]This rate is calculated as the ratio between the amount of reserves and the total deposits plus short and long term obligations. See appendix A for further details.

amount of reserves, reserve ratios and interest rate spreads all react positively to a RR shock, but we also assume that Net International Reserves (NIR) go down in the short run. NIRs go down because banks press to buy dollars in exchange for domestic currency and the central bank sells some of the dollars banks need. As the central bank sells dollars, it losses foreign exchange reserves. But in the adjustment process, NIR will tend to increase because the dollars in the hand of banks will be deposited back at the central bank. On the other hand, we are agnostic about the response of the rest of variables included in the SVAR.

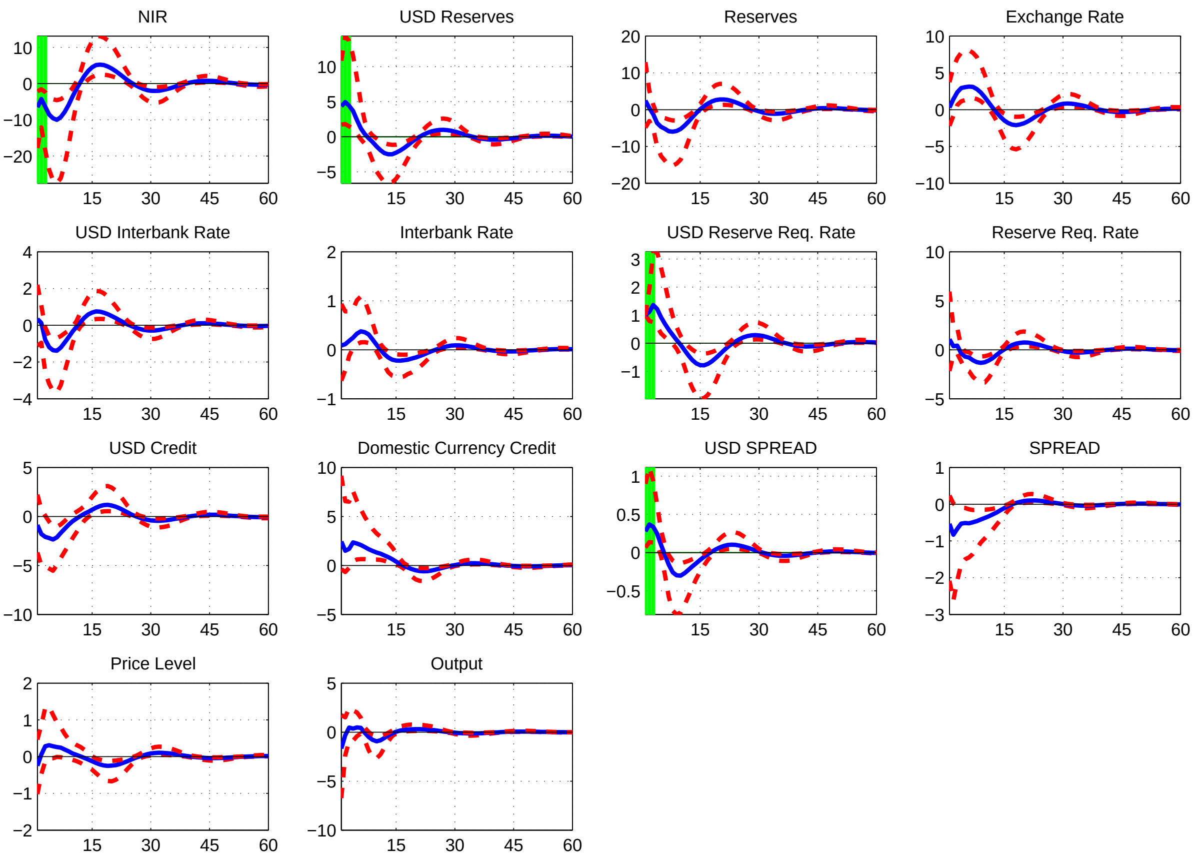
Table 3. *Zero and sign restrictions about the effects of a reserve requirement shock in foreign currency over macroeconomic variables*

Variables	RR shock	
	$t = 0$	$t = 1, 2$
Net International Reserves	$\leqslant 0$	$\leqslant 0$
Amount of reserves (USD)	$\geqslant 0$	$\geqslant 0$
Amount of reserves	?	?
Exchange rate	?	?
Interbank rate (USD)	?	?
Interbank rate	?	?
Reserve ratio (USD)	$\geqslant 0$	$\geqslant 0$
Reserve ratio	?	?
Credit level (USD)	0	?
Credit level	0	?
Interest rate spread (USD)	$\geqslant 0$	$\geqslant 0$
Interest rate spread	0	?
Price level	0	?
Real product	0	?

Results are depicted in Figure 5. In particular, a raise in foreign currency reserve requirements does produce a negative effect on US-dollar credit. The maximum result is achieved by mid year after the shock and seems robust. The effects on the rest of the variables are more uncertain (confidence bands are wide). The uncertainty stems from the fact that, in the case of a rise in USD reserve requirements, banks can switch easily to other sources of funding such us borrowing from external credit lines and thus can restore or maintain desired levels of credit.

Abstracting from uncertainty, the results can be still rationalized in terms of our framework in Figure 3. A rise in foreign currency reserve requirements induces banks, in the short run, to demand more US-dollar liquid assets. This causes exchange rate depreciation pressures that trigger central bank intervention on the dollar sale side. This means that NIRs fall in the short run as shown in Figure 5 but on the other hand, NIRs should also increase because a huge bulk of higher reserve requirements end up as deposits at the central bank. In the short run, the sale of US dollars by the central bank dominates the dynamics of reserves.

Figure 5. *Effects of a 1% foreign currency reserve requirement shock; median value and 66% bands*



We observe that the exchange rate depreciates due to the shock. However, our sample size spans precisely over the period of capital inflows which means that exchange rate appreciations were more common and usual than depreciation movements. Then, a possible hypothesis is that banks might have not be so willing to reduce their domestic-currency liquid assets in exchange for more US-dollar liquid assets. Therefore, credit levels in domestic currency tended to remain fixed. This result contrasts to our previous finding that an increase in domestic reserve requirements does change US-dollar credit, but is consistent with the perception of banks that exchange rate appreciations were the norm in this era while exchange rate depreciations were at odds with the persistent capital inflow environment.

The effect on the rest of the variables seems statistically irrelevant. The effect of shocks on reserve requirements on foreign currency deposits is the fall in loans granted in US dollars.

8 Concluding Remarks

In this document we identify a SVAR model imposing zero and sign restrictions, in the spirit of Arias *et al.* (2014), in order to pin down the dynamic effects of conventional and unconventional monetary shocks in Peru. The former is associated with interbank interest rates and the latter with reserve requirement rates.

The first finding of the paper is that standard interest rate policy shocks can be found in Peruvian data as described by Rossini and Vega (2007), i.e. a tight monetary policy generates an appreciation of the domestic currency and a fall in both output and prices. These shocks are also useful for controlling credit growth dynamics in both domestic and foreign currency, and we also find evidence of a rise in interest rates spreads between loan and deposit rates. These results about the conventional effects of monetary policy are compatible with the general literature and the specific literature for Peru.

The second key finding of the paper is that a rise in the reserve requirements rates in both currencies can reduce lending levels. A rise in domestic-currency reserve requirements reduce both; domestic-currency and US-dollar credit levels. The fact that US-dollar lending falls more persistently is explained by i) a strong liquidity channel that operates due to the willingness of banks to hold less dollar liquidity and more domestic-currency liquidity after the domestic-currency reserve requirement rises and ii) because output falls, though mildly, and thus pushes lending levels a bit downwards.

Instead, a rise in US-dollar reserve requirements essentially only reduces US-dollar credit. The liquidity channel, based on the liquidity swapping observed in the previous paragraph, does not operate here to reduce domestic-currency lending. This may be due to the low willingness of banks to sacrifice domestic-currency assets in an era of exchange rate appreciations linked to the capital inflow period governing all the sample period.

These results are interesting because they can be guides for structural model building that integrates the presence of conventional monetary policy and the two types of reserve requirements in a dynamic setting with banks. With this type of model we could also identify the relative merits of the various channels that interact in this three-policy setting.

The findings are also important as policy guides. We can see that conventional monetary policy is better suited to control prices and output whereas their effect on lending activity is weaker compared to reserve requirement policies. Therefore, reserve requirement policies are a convenient way to complement monetary policy with financial stability considerations.

A Data Description

We include raw data for the period 1995:10-2013:12

A.1 Domestic variables

- Stock of Reserves in soles and US dollars (mandatory plus voluntary), in logs: Reserves
- Exchange Rate Sol per US dollar, in logs: ER
- Interbank Rate (INT) in soles and US dollars, in %.
- Effective Reserve Requirements Rate in soles and US dollars, in %. (RR). Effective rate is measured as the the total amount of reserves (mandatory plus voluntary) divided by the total amount of deposits or obligations. For U.S. dollar-denominated reserve requirements, an augmented reserve requirement ratio has to be constructed in order to account for the fact that banks can more easily substitute this source of funding via external liabilities or with bond issues. Hence, an augmented effective reserve ratio is constructed by dividing the amount of U.S. dollar reserves by the sum of augmented U.S. dollar liabilities. Augmented U.S. dollar liabilities include dollar deposits, external debt, and bond issues.
- Bank Credit to the Private Sector in soles and US dollars, in logs (Credit)
- Spread between Average Loan Rate (TAMN,TAMEX) minus Average Deposit Rate (TIPMN,TIPMEX): SPREAD
- Consumer Price Index of Lima (2009=100), in logs: CPI
- Real Gross Domestic Product Index of Peru (1994=100), in logs: GDP

- Net International Reserves in Millions of US dollars, in logs.

All variables in logs were multiplied by 100, so that the impulse responses can be interpreted as percentage changes. Peruvian data is from the central bank website and United States data is obtained from FRED database. Nevertheless, we only have available data for reserves ratio (RR) and the amount of reserves in foreign currency (dollars) since 2001:12. Therefore, the results of the last exercise are based on the sample 2001:12-2013:11.

A.2 Exogenous variables ($\mathbf{w}_t$)

- Terms of trade index (1994=100), in logs.
- Commodity prices index (All commodities), in logs.
- Federal Funds Rate, in %.
- Seasonal dummy variables.
- D_1: Inflation Targeting dummy variable (2002:02-2013:12)
- D_2: Financial turmoil dummy variable (2008:09-2013:12)
- D_3: Quantitative Easing dummy variable (2010:09-2013:12)
- Constant and quadratic time trend (t^2)[7].

B Estimation details

This section closely follows the work of Arias *et al.* (2014).

[7] The interactions of these trends with D_1, D_2 and D_3 are also included as exogenous variables

B.1 Implementing zero restrictions

For any orthogonal matrix $\mathbf{Q}$, zero restrictions hold if

$$\mathbf{Z}_j f(\mathbf{A}_0, \mathbf{A}_+)\mathbf{Q}\mathbf{e}_j = \mathbf{Z}_j f(\mathbf{A}_0, \mathbf{A}_+)\mathbf{q}_j = 0; \text{ for } j = 1, \ldots, n$$

In short, zero restrictions are linear restrictions in the columns of $\mathbf{Q}$. As a matter of fact, Theorem 2 of Arias *et al.* (2014) says that $\mathbf{Q}$ satisfies the zero restrictions if and only if $\left\|\mathbf{q}_j\right\| = 1$ and

$$\mathbf{Z}_j \mathbf{R}_j(\mathbf{A}_0, \mathbf{A}_+)\mathbf{q}_j = 0; \text{ for } j = 1, \ldots, n$$

where

$$\mathbf{R}_j(\mathbf{A}_0, \mathbf{A}_+) \equiv \begin{bmatrix} \mathbf{Z}_j f(\mathbf{A}_0, \mathbf{A}_+) \\ \mathbf{Q}_{j-1} \end{bmatrix}$$

and $rank\left(\mathbf{Z}_j\right) \leq n - j$, $\mathbf{Q}_{j-1} = \begin{bmatrix} \mathbf{q}_1 & \cdots & \mathbf{q}_{j-1} \end{bmatrix}$.

Moreover, Theorem 3 of Arias *et al.* (2014) shows how to obtain a $\mathbf{Q}$ that satisfies the zero restrictions given $j = 1$:

1. Compute $\mathbf{N}_j$, the basis for the null space $\mathbf{R}_j(\mathbf{A}_0, \mathbf{A}_+)$.
2. Draw $\mathbf{x}_j \sim N(0, I_n)$.
3. Compute $\mathbf{q}_j = \mathbf{N}_j\left(\mathbf{N}_j'\mathbf{x}_j\right) / \left\|\mathbf{N}_j'\mathbf{x}_j\right\|$.
4. If $j = n$ stop, otherwise set $j = j + 1$ and go to step 1.

The random matrix $\mathbf{Q} = \begin{bmatrix} \mathbf{q}_1 & \cdots & \mathbf{q}_n \end{bmatrix}$ has the uniform distribution with respect to the Haar measure on $O(n)$, conditional on $(\mathbf{A}_0\mathbf{Q}, \mathbf{A}_+\mathbf{Q})$ satisfying the zero restrictions.

B.2 Implementing sign restrictions

It is standard in the literature (see e.g. Canova and De Nicoló (2002), Uhlig (2005) and Amir-Ahmadi and Uhlig (2009)) to implement sign restrictions as follows:

1. Draw $(\mathbf{B}, \Sigma)$ from the posterior distribution.

2. Denote $\mathbf{T}$ such that $(\mathbf{A}_0, \mathbf{A}_+) = \left(\mathbf{T}^{-1}, \mathbf{B}\mathbf{T}^{-1}\right)$.

3. Draw a $n \times n$ matrix $\mathbf{X} \sim MN_n$ (standard normal distribution).

4. Recover $\mathbf{Q}$ such that $\mathbf{X} = \mathbf{Q}\mathbf{R}$ is the QR decomposition. $\mathbf{Q}$ is therefore a random matrix with a uniform distribution with respect to the Haar measure on $O(n)$.

5. Keep the draw if $\mathbf{S}_j f\left(\mathbf{T}^{-1}, \mathbf{B}\mathbf{T}^{-1}\right)\mathbf{Q}\mathbf{e}_j > 0$ is satisfied.

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