The dynamic effects of interest rates and reserve requirements in Peru: A zero-sign restrictions approach

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Motivation

- Since the outbreak of the Global Financial Crisis of 2007-2008, monetary policies in developed and emerging economies rely more on a varied set of Unconventional Policy Instruments to achieve macroeconomic and financial stability.
- Reserve Requirements (RR) have been used by a number of emerging market countries as a non-conventional monetary policy tool (see Montoro & Moreno, 2011; Tovar et al.,2012; among others.
- Even though reserve requirements have been abandoned in most developed economies, they have been actively used in the emerging world, specially after the global financial crisis. This has been the case for example in Peru (Armas et al., 2014).
- In this paper we explore the transmission mechanisms of the two types of policies in Peru.

Motivation

- Since the adoption of the Inflation Targeting (IT) regime in 2002, the BCRP implements its policy by setting a reference interbank interest rate (Rossini & Vega, 2007), given the reserve requirement rates (RR).
- Nevertheless, due to the global financial turmoil of 2008, the BCRP started using RR policies actively in both domestic and foreign currency for monetary control purposes (to fight credit growth dynamics related to capital inflows). However, RR were used for implementing monetary policy even in the period previous to IT (See Montoro & Moreno, 2011; Armas et al., 2014).
- Nowadays RR are still used for monetary control in conjunction with the interest rate, but their role is now classified as macro-prudential (see Rojas (2010), Leon & Quispe (2011), Tovar et al. (2012)).

Motivation

- In this document we present a unified framework where we can identify both INT and RR shocks.
- To do so, we impose a mix of zero and sign restrictions in a Structural Vector Autoregressive (SVAR) model for the Peruvian Economy (Arias et al., 2014).
- Crucially, we set these restrictions based on the conventional wisdom about the main characteristics of the two mentioned shocks.

Main findings

- We find that INT is useful for controlling the evolution of output and prices, whereas RR is useful for controlling credit.
- Moreover, unlike INT shocks, RR shocks do not produce significant effects on exchange rates.
- There are differences in impact and propagation of the two shocks, i.e impulse responses are hump-shaped.
- Our results are in line with other empirical studies such as Tovar et.al (2012), Glocker & Towbin (2015) and Armas et al. (2014) and also with theoretical approaches such as Romer(1985), Betancourt & Vargas (2009), Montoro and Tovar (2010), Montoro (2011), Carrera Vega (2012), Glocker & Towbin (2012).

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Monetary Policy practices in Peru

- The BCRP has implemented its Monetary Policy in the past using money aggregates until the adoption of Inflation Targeting in 2002, when it started to use the Interbank Interest Rate (INT) as the operational target Rossini & Vega (2007).
- As a matter of fact, before 2002 RR and Money Aggregates were crucial for explaining the Inflation rate process Armas et al. (2001), and they were actively used as policy instruments De la Rocha (1998).
- On the other hand, since 2008 RR have been actively used, now with macro-prudential purposes; see Rojas (2010) and Leon & Quispe (2011).

Empirical evidence for Peru

- The effects of monetary policy shocks identified through the interest rates have been deeply investigated for the case of Peru in the past; see e.g. the work of Winkelried (2004), Bigio & Salas (2006), Castillo et al. (2010), Lahura (2010), among others.
- This is the first paper that investigates the role of INT together with RR in a dynamic setup.

Empirical evidence for Peru

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.

Table: Empirical evidence of Interest Rate shocks in Peru Lahura (2012)

The SVAR model

- Consider the SVAR model

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

- $\mathbf{y}_t$ 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 $i = 0, \ldots, p$.
- $\mathbf{c}$ 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 model

- The SVAR can be written as

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

where

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

- Reduced form:

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

- $\mathbf{B} \equiv \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t' \equiv \varepsilon_t'\mathbf{A}_0^{-1}$, and $E\left[\mathbf{u}_t\mathbf{u}_t'\right] = \mathbf{\Sigma} = \left(\mathbf{A}_0\mathbf{A}_0'\right)^{-1}$.
- $(\mathbf{B}, \mathbf{\Sigma}) \Rightarrow$ Reduced-form parameters.
- $(\mathbf{A}_+, \mathbf{A}_0) \Rightarrow$ Structural parameters.

Impulse Responses

- The cumulative impulse responses are:

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

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

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Identification

We impose two sets of restrictions:

- The first group is related with zero restrictions in the contemporaneous coefficients matrix, as in the old literature of Structural VARs (Sims, 1980).
- The second group are the sign restrictions as in Canova & De Nicol'o (2002), where we set a horizon of three months.

These identifying restrictions are displayed in the following table.

Identification

Table: 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.

INT shocks RR shocks

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The algorithm

1. Draw $(\mathbf{B}, \mathbf{\Sigma})$ from the posterior distribution.
2. Denote $\mathbf{T}$ such that $(\mathbf{A}_0, \mathbf{A}_+) = \left(\mathbf{T}^{-1}, \mathbf{BT}^{-1}\right)$ and draw an orthogonal matrix $\mathbf{Q}$ such that $\left(\mathbf{T}^{-1}\mathbf{Q}, \mathbf{BT}^{-1}\mathbf{Q}\right)$ satisfy the zero restrictions. ▸ Zero Restrictions
3. Keep the draw if $\mathbf{S}_j f\left(\mathbf{T}^{-1}\mathbf{Q}, \mathbf{BT}^{-1}\mathbf{Q}\right)\mathbf{e}_j > 0$ is satisfied (if sign restrictions hold). ▸ Sign Restrictions
4. Return to Step 1 until the required number of posterior draws satisfying both the sign and zero restrictions have been obtained.

▸ Data Description

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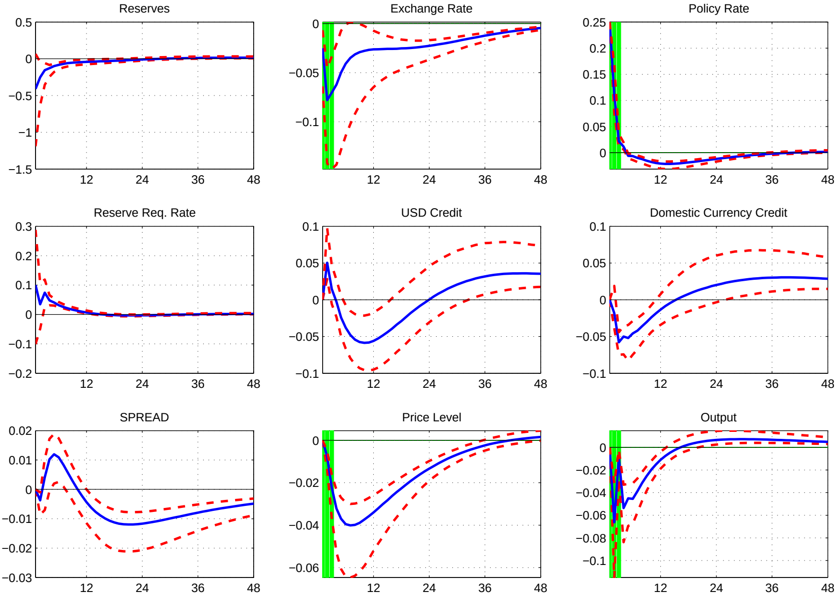


Figure: Interest Rate shock of 0.25%; median value and 66% bands

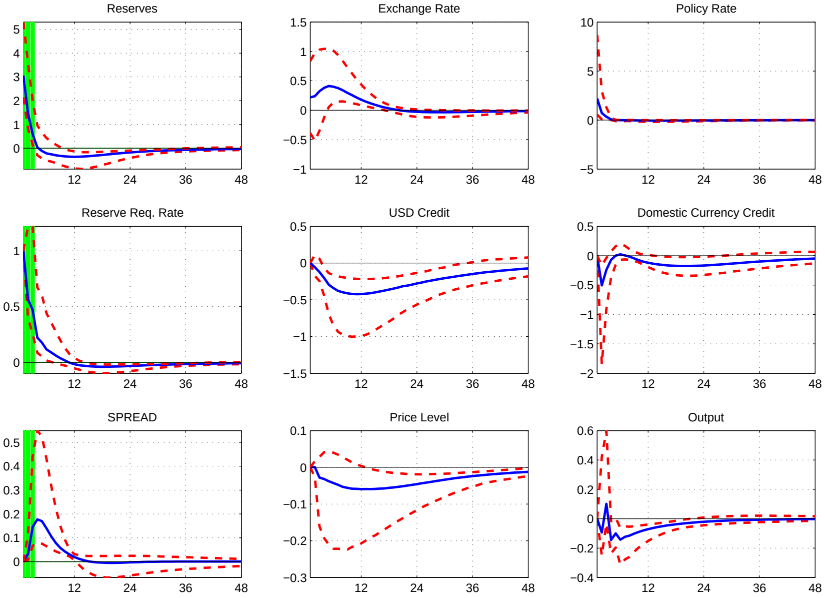
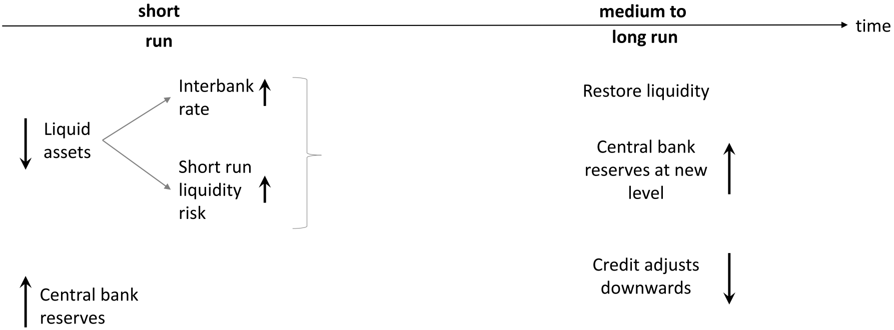


Figure: Reserve requirement shock of 1%; median value and 66% bands

Figure: Short and long-run effects of a rise in reserve requirements



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Identification

Table: 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	?	?
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	?

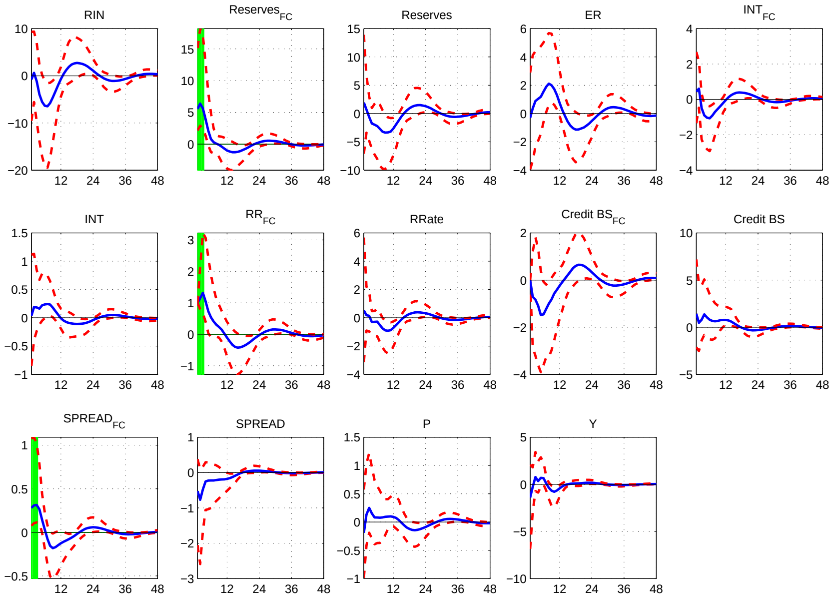
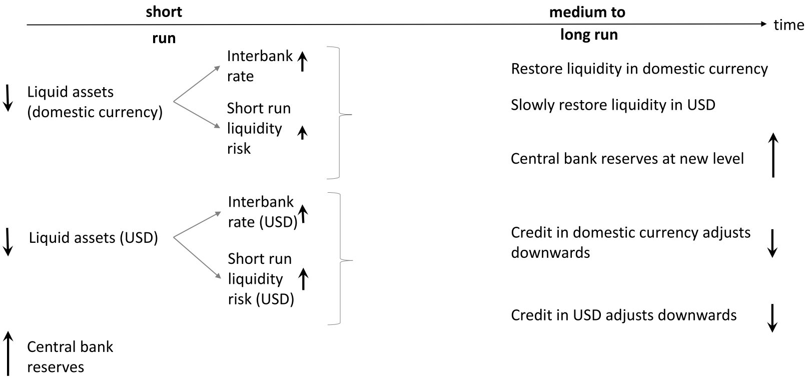


Figure: Peru: Reserve requirement shock of 1% in foreign currency; median value and 66% bands

Figure: Effects of a rise in reserve requirements under a dollarized financial system



Concluding Remarks

- 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 (INT) and the latter with reserve requirement rates (RR).
- Main findings: i) Standard INT policy shocks can be found in the data as described by Rossini & Vega (2007). ii) A rise in the RR rates in both currencies can reduce the level of aggregate credit (in both domestic and foreign currency).

Implementing Zero restrictions I

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

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

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 iff $\|\mathbf{q}_j\| = 1$ and

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

where

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

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 $j = 1$:

Implementing Zero restrictions II

1. Compute $\mathbf{N}_j$, the basis for the null space $\mathbf{R}_j\left(\mathbf{A}_0, \mathbf{A}_+\right)$.
2. Draw $\mathbf{x}_j \sim N\left(0, I_n\right)$.
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 $\mathbf{Q} = \left[\begin{array}{ccc} \mathbf{q}_1 & \cdots & \mathbf{q}_n \end{array}\right]$ has the uniform distribution with respect to the Haar measure on $O\left(n\right)$, conditional on $\left(\mathbf{A}_0\mathbf{Q}, \mathbf{A}_+\mathbf{Q}\right)$ satisfying the zero restrictions. Back

Implementing Sign restrictions

It is standard in the literature to implement sign restrictions as follows:

1. Draw $(\mathbf{B}, \mathbf{\Sigma})$ 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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Data Description I

Endogenous variables ($\mathbf{y}_t$):

- 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)[1]
- 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

Data Description II

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

We include raw data for the period 1995:10-2013:12. All variables in logs were multiplied by 100, so that the impulse responses can be interpreted as percentage changes. Peruvian data is from the BCRP 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. Back

[1] Effective rate is measured as the the Total Amount of Reserves (mandatory plus voluntary) divided by the Total amount of Deposits or Obligations.

Data Description

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)[2].

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

Interest rate shocks

- We take the benchmark specification of a monetary shock from Canova Paustian (2011).
- We extend the latter for the Peruvian case following the mechanism described in Rossini & Vega (2007).
- Unlike Glocker & Towbin (2015), we identify INT shocks by restricting output (GDP), prices (CPI) and the exchange rate (ER), and we do not restrict the amount of reserves.

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Reserve Requirement shocks

- We set a positive response of Reserves and a positive response of interest rate spreads. The latter is based on evidence of faster responses of loan interest rates than deposit ones (Lahura, 2005; Leon & Quispe, 2011), a negative response of deposit rates Condor (2010).
- These assumptions are also based on theoretical models that link reserve requirements with interest rates such as Betancourt & Vargas (2009), Carrera & Vega (2012) and Glocker & Towbin (2012).

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Thanks