Assessing the effect of US Monetary Policy Normalization on Latin American Economies*

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This draft: 31st March 2017

Abstract

As a response of the Financial Crisis of 2008, the Fed implemented a expansionary monetary policy by cutting the Federal Funds Rate (FFR) until reaching the zero lower bound (ZLB) and performing unconventional policies named the Quantitative Easing (QE). After several years, and since the US economy is in a different state, the Fed has started removing this monetary stimulus. This paper quantifies the effects of this monetary policy normalization by identifying US monetary policy shocks. In addition, we also assess the effect of the systematic component of monetary policy normalization by identifying demand and supply shocks, since the latter could also cause a hike in the policy rate according to a textbook Taylor rule. After that, we assess the spillover effects of these structural disturbances to different Latin American (LATAM) economies using a Structural Vector Autoregresive (SVAR) model with block exogeneity, which is identified through sign and zero restrictions. In particular, we focus our attention in four Inflation Targeting countries, i.e. Chile, Colombia, Mexico and Peru, and we use Bayesian techniques in order to quantify the uncertainty of the impulse response estimates. The results show that US interest rate shocks produce in LATAM a nominal depreciation, a positive reaction of the domestic interest rate and inflation and fall in aggregate credit and GDP. Moreover, US demand and supply shocks also generate a fall in GDP and aggregate credit in domestic currency, though, they in general produce mixed effects for LATAM variables. Nevertheless, the effects derived from US demand and supply shocks are less significant and more uncertain than the monetary ones, since they come from monetary actions that were predicted by the market.

JEL Classification: E43, E51, E52, E52, E58

Key words: Unconventional Monetary Policy, Monetary Policy Normalization, Structural VAR, Block Exogeneity, Gibbs sampling, Sign Restrictions

*I would like to thank Paul Castillo, Nathan Converse, Marco Ortiz, seminar participants in Managing Macroeconomic Risks and Controlling Inflation: Challenges for emerging market economies (CEMLA, BCRP, CME) and participants of the XX Annual Meeting of the Central Bank Researchers Network (CEMLA) for their helpful comments and suggestions. The views expressed are those of the author and do not necessarily reflect those of the Central Bank of Peru. All remaining errors are mine.

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1 Introduction

As a response of the Financial Crisis of 2008, the Federal Reserve of the United States (Fed) lowered the Federal Funds Rate (FFR) until reaching the Zero Lower Bound (ZLB). The latter was implemented with the purpose of fostering economic activity, in the context of the so-called Great Recession. The binding restriction of the ZLB prevented the Fed of having a loose monetary policy stance, which was desired given the dual mandate of price stability and maximum employment[1]. Because of this ZLB restriction, the Fed started using alternative instruments in order to get a looser monetary policy. In particular, the Fed started increasing the size of its balance sheet by buying exceptionally large quantities of assets (Cúrdia and Woodford, 2011). As it is explained by Baumeister and Benati (2013), the latter had also the purpose of lowering long term interest rates, since this could be considered as a plausible strategy for getting a loose stance of monetary policy. The exceptional practice of monetary policy was denominated Quantitative Easing (QE), and it has been demonstrated that it produced significant nominal and real effects over several macroeconomic variables around the globe, both in advanced economies (Baumeister and Benati, 2013) and also in emerging economies (see e.g. Carrera et al. (2015), among others). Moreover, we can also find evidence for Latin America

After seven years of the application of the Quantitative Easing, the Fed has started removing the monetary stimulus. This comes after the so called *Tapering Talk* in May of 2013 and because of the communication strategy followed by the Fed, in terms of setting a monetary policy conditional on the state of the economy. Moreover, nowadays the Fed has raised the FFR in December 2015, December 2016 and in March 2017. In practice, Monetary Policy normalization actions[2] will be centered in i) Raising short-term interest rates[3] and ii) Reducing the size of the Fed's Balance Sheet (Williamson, 2015). In this context, it is important to isolate the surprise component of this policy action, since now the US economic indicators suggest some signals of recovery. That is, it might be case that part of the monetary policy normalization has been already internalized by the economic agents in the private sector, both in the US and in

[1] https://www.federalreserve.gov/faqs/money$_1$2848.*htm*

[2] https://www.federalreserve.gov/monetarypolicy/policy-normalization.htm

[3] https://www.stlouisfed.org/annual-report/2015/what-is-monetary-policy-normalization

emerging economies, e.g. updated expectations in the financial markets, observed demand and supply shocks, etc. Therefore, our purpose in this paper is to disentangle the dynamic effects of unexpected movements in the FFR with respect to the systematic reaction of the Fed after demand and supply shocks, i.e. the typical Taylor rule that can be found in popular textbooks related with monetary policy (see e.g. Woodford (2003) and Gali (2015)).

Moreover, it is somewhat obvious to consider the fact that this monetary policy normalization will have a direct impact on Latin American Economies. The question is then how is the transmission mechanism of these policy actions from the US and what are the spillover macroeconomic effects over Latin American Economies. We focus our attention on four countries that apply the Inflation Targeting as a monetary policy scheme (see e.g. Pérez Forero (2015)). The estimation of these effects are extremely relevant for Latin American economies, because it will give us some light about the possible future challenges of policy makers, especially central banks. That is, the empirical exercise proposed in this paper will show us all the possible dynamic effects that Latin American economies will face after the introduction of the mentioned policy normalization.

In order to assess these mentioned dynamic effects, I estimate a Structural Vector Autorregressive model (see e.g. Sims (1980), Sims (1986)). In this case, consider a small open economy setup, where the big economy is the United States (US) and the Small economy is the Latin American One (e.g. Chile, Colombia, Mexico or Peru). It is then clear that shocks affecting the US can be transmitted to the Latin American countries, but not the other way around. Therefore, we assume a Block Exogeneity structure as in Cushman and Zha (1997), Zha (1999) and Canova (2005). That is, Latin American shocks do not affect the US economy. The statistical model is estimated using Markov Chain Monte Carlo (MCMC) Bayesian Methods (see Zellner (1971), Koop (2003)) via Gibbs Sampling (see e.g. Canova (2007) and Koop and Korobilis (2010)). Given the estimated statistical model, we identify the structural monetary policy shock by imposing sign restrictions as in Canova and De Nicoló (2002), Uhlig (2005) and recently by Arias et al. (2014)[4]. Recent approaches for small open economies can also be found in Carrera et al. (2015), Dahlhaus and Vasishtha (2014) and in Pagliacci (2014), among others.

[4]See also Rubio-Ramírez et al. (2010) and Kilian (2011) for a general discussion about identification in SVARs.

An identified US interest rate shock through sign and zero restrictions produces a typical textbook effect, i.e. an increase in the FFR is followed by a fall in money growth, output and inflation. In addition, this shock is transmitted to the small open economy and produces a nominal depreciation and a positive reaction of the domestic interest rate. Moreover, the tighter external monetary policy produces, in most cases, a negative effect in aggregate credit, economic activity and a positive effect in inflation. Our results are in line with Canova (2005) and, more importantly, we take into account the Unconventional Monetary Policy (UMP) period when performing the estimation. Therefore, our results are not biased, in sense that the identified shocks are easy to interpret, since they correspond to the period starting after 2007, and they have nothing to do with previous periods. It is important to remark that some differences can be observed across country impulse responses. In particular, the response of the depreciation rate is more persistent in Chile and Peru rather than in Mexico and Colombia.

Regarding the Interest Rate shocks, my work is slightly different with respect to other attempts in this theme. First, we only measure movements in the shadow FFR (Wu and Xia, 2015), whereas Dahlhaus and Vasishtha (2014) measures the effects of announcements, expectations, etc. On the other hand, Pagliacci (2014) uses an alternative identification strategy without sign restrictions and also a different set of variables and countries. The research agenda is very large and vast. For instance, we do not include Balance Sheet variables such as Total Reserves, etc. That is, a plausible extension would be to explicitly model the operating procedures of the Fed as in Bernanke and Mihov (1998), but right now this is out of the scope of this paper. Finally, since sign restrictions only capture a large set of possible micro-founded models that can reproduce the same shock, then the next step is to construct a stylized model with all these mechanisms and channels.

In this paper I also identify demand and supply shocks for the US economy. The latter is important since these forces can also trigger a hike in the FFR, and the latter will be completely different from a monetary policy surprise. As a matter of fact, if the interest rate is raised because of demand and supply shocks, it is likely that the market has already internalized and anticipated those effects. Therefore, the surprise component must be disentangled from these effects, and in general this is a difficult task. Results show that a US interest rate shock produces a nominal depreciation and a positive reaction of the domestic interest rate. Furthermore, in most cases the identified external monetary shock affects negatively in aggregate credit (in both currencies), economic activity and inflation. On the other hand, demand and supply shocks have mixed and uncertain effects across LATAM economies. Perhaps more work is needed in terms of imposing more restrictions to properly identify both demand and supply shocks, since it is widely accepted in the literature that sign restrictions are relatively weak. On the other hand, given the reduced span of data (2007-2016), it is natural to observe a considerable amount of uncertainty, and this could be fixed by considering tighter priors. Perhaps more work is needed in terms of imposing more restrictions to properly identify supply shocks, since it is widely accepted in the literature that sign restrictions are relatively weak. On the other hand, given the reduced span of data (2007-2016), it is natural to observe a considerable amount of uncertainty, and this could be fixed by considering additional plausible restrictions in order to properly isolate the three structural shocks mentioned in this document.

The document is organized as follows: section 2 describes the econometric model, section 3 describes the estimation procedure, section 4 explains the identification strategy, section 5 discusses the main results, and section 6 concludes.

2 A SVAR model with block exogeneity

2.1 The setup

Consider a big economy (the US) modeled as an independent Vector Autoregressive system (VAR) and also a small open economy modeled as a Vector Autoregressive system with exogenous variables, which are basically the US economy elements (VARX). In this context, the big economy is represented for $t = 1, ..., T$ by

$$\mathbf{y}_t^{*\prime}\mathbf{A}_0^* = \sum_{i=1}^{p} \mathbf{y}_{t-i}^{*\prime}\mathbf{A}_i^* + \mathbf{w}_t^{\prime}\mathbf{D}^* + \varepsilon_t^{*\prime}, \tag{1}$$

where y_t^* is $n^* \times 1$ vectors of endogenous variables for the big economy; ε_t^* is $n^* \times 1$ vectors of structural shocks for the big economy ($\varepsilon_t^* \sim N(0, I_{n^*})$); $\widetilde{\mathbf{A}}_i^*$ and $\mathbf{A}_i^*$ are $n^* \times n^*$ matrices of structural parameters for $i = 0, \ldots, p$; $\mathbf{w}_t$ is a $r \times 1$ vector of exogenous variables; $\mathbf{D}^*$ is $r \times n$ matrix of structural parameters; p is the lag length; and, T is the sample size.

The small open economy is represented by

$$\mathbf{y}_t'\mathbf{A}_0 = \sum_{i=1}^{p} \mathbf{y}_{t-i}'\mathbf{A}_i + \sum_{i=0}^{p} \mathbf{y}_{t-i}^{*\prime}\widetilde{\mathbf{A}}_i^* + \mathbf{w}_t'\mathbf{D} + \varepsilon_t', \tag{2}$$

where y_t is $n \times 1$ vector of endogenous variables for the small economy; ε_t is $n \times 1$ vector of structural shocks for the domestic economy ($\varepsilon_t \sim N(0, I_n)$ and structural shocks are independent across blocks i.e. $E(\varepsilon_t \varepsilon_t^{*\prime}) = \mathbf{0_{n \times n^*}}$); $\mathbf{A}_i$ are $n \times n$ matrices of structural parameters for $i = 0, \ldots, p$; and, $\mathbf{D}$ is $r \times n$ matrix of structural parameters. The latter model can be expressed in a more compact form, so that

$$\begin{aligned}
\begin{bmatrix} \mathbf{y}_t' & \mathbf{y}_t^{*\prime} \end{bmatrix} \begin{bmatrix} \mathbf{A}_0 & \mathbf{0} \\ -\widetilde{\mathbf{A}}_0^* & \mathbf{A}_0^* \end{bmatrix} &= \sum_{i=1}^{p} \begin{bmatrix} \mathbf{y}_{t-i}' & \mathbf{y}_{t-i}^{*\prime} \end{bmatrix} \begin{bmatrix} \mathbf{A}_i & \mathbf{0} \\ \widetilde{\mathbf{A}}_i^* & \mathbf{A}_i^* \end{bmatrix} \\
&\quad + \mathbf{w}_t' \begin{bmatrix} \mathbf{D} \\ \mathbf{D}^* \end{bmatrix} + \begin{bmatrix} \varepsilon_t' & \varepsilon_t^{*\prime} \end{bmatrix} \begin{bmatrix} I_n & \mathbf{0} \\ \mathbf{0} & I_{n^*} \end{bmatrix},
\end{aligned}$$

or simply

$$\vec{\mathbf{y}}_t' \vec{\mathbf{A}}_0 = \sum_{i=1}^{p} \vec{\mathbf{y}}_{t-i}' \vec{\mathbf{A}}_i + \mathbf{w}_t' \vec{\mathbf{D}} + \vec{\varepsilon}_t', \tag{3}$$

where $\vec{\mathbf{y}}_t' \equiv \begin{bmatrix} \mathbf{y}_t' & \mathbf{y}_t^{*\prime} \end{bmatrix}$, $\vec{\mathbf{A}}_i \equiv \begin{bmatrix} \mathbf{A}_i & \mathbf{0} \\ \widetilde{\mathbf{A}}_i^* & \mathbf{A}_i^* \end{bmatrix}$ for $i = 1, \ldots, p$, $\vec{\mathbf{D}} \equiv \begin{bmatrix} \mathbf{D} \\ \mathbf{D}^* \end{bmatrix}$ and $\vec{\varepsilon}_t' \equiv \begin{bmatrix} \varepsilon_t' & \varepsilon_t^{*\prime} \end{bmatrix}$.

The system (2) represents the small open economy in which its dynamic behavior is influenced by the big economy block (1) through the parameters $\widetilde{\mathbf{A}}_i^*, \mathbf{A}_i^*$ and $\mathbf{D}^*$. On the other hand, the big economy evolves independently, i.e. by construction, the small open economy cannot influence the dynamics of the big economy.

Even though block (1) has effects over block (2), we assume that the block (1) is independent of block (2). This type of *Block Exogeneity* has been applied in the context of SVARs by Cushman and Zha (1997), Zha (1999) and Canova (2005), among others. Moreover, it turns out that this is a plausible strategy for representing small open economies such as the Latin American ones, since they are influenced by external shocks such as the mentioned Unconventional Monetary Policy (UMP) measures implemented in the U.S. economy.

2.2 Reduced form estimation

The system (3) is estimated by block separately. We first present a foreign, then a domestic block, and finally introduce a compact form system i.e. stack both blocks into a one system.

2.2.1 Big economy block

The independent SVAR (1) can be written as

$$\mathbf{y}_t^{*\prime}\mathbf{A}_0^* = \mathbf{x}_t^{*\prime}\mathbf{A}_+^* + \varepsilon_t^{*\prime} \quad \text{for } t = 1, \ldots, T;$$

where

$$\mathbf{A}_+^{*\prime} \equiv \left[\begin{array}{cccc} \mathbf{A}_1^{*\prime} & \cdots & \mathbf{A}_p^{*\prime} & \mathbf{D}^{*\prime} \end{array} \right], \; \mathbf{x}_t^{*\prime} \equiv \left[\begin{array}{cccc} \mathbf{y}_{t-1}^{*\prime} & \cdots & \mathbf{y}_{t-p}^{*\prime} & \mathbf{w}_t' \end{array} \right],$$

so that the reduced form representation is

$$\mathbf{y}_t^{*\prime} = \mathbf{x}_t^{*\prime}\mathbf{B}^* + \mathbf{u}_t^{*\prime} \quad \text{for } t = 1, \ldots, T; \tag{4}$$

where $\mathbf{B}^* \equiv \mathbf{A}_+^* \left(\mathbf{A}_0^*\right)^{-1}$, $\mathbf{u}_t^{*\prime} \equiv \varepsilon_t^{*\prime} \left(\mathbf{A}_0^*\right)^{-1}$, and $E\left[\mathbf{u}_t^{*}\mathbf{u}_t^{*\prime}\right] = \mathbf{\Sigma}^* = \left(\mathbf{A}_0^*\mathbf{A}_0^{*\prime}\right)^{-1}$. Then the coefficients $\mathbf{B}^*$ are estimated from (4) by OLS.

2.2.2 Small open economy block

The SVARX system (2) is written as

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

where

$$
\begin{aligned}
\mathbf{A}'_+ &\equiv \begin{bmatrix} \mathbf{A}'_1 & \cdots & \mathbf{A}'_p & \widetilde{\mathbf{A}}^*_0 & \widetilde{\mathbf{A}}^*_1 & \cdots & \widetilde{\mathbf{A}}^*_p & \mathbf{D}' \end{bmatrix} \\
\mathbf{x}'_t &\equiv \begin{bmatrix} \mathbf{y}'_{t-1} & \cdots & \mathbf{y}'_{t-p} & \mathbf{y}^{*\prime}_t & \mathbf{y}^{*\prime}_{t-1} & \cdots & \mathbf{y}^{*\prime}_{t-p} & \mathbf{w}'_t \end{bmatrix}.
\end{aligned}
$$

The reduced form is now

$$\mathbf{y}'_t = \mathbf{x}'_t\mathbf{B} + \mathbf{u}'_t \quad \text{for } t = 1, \ldots, T; \tag{5}$$

where $\mathbf{B} \equiv \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}'_t \equiv \varepsilon'_t\mathbf{A}_0^{-1}$, and $E\left[\mathbf{u}_t\mathbf{u}'_t\right] = \mathbf{\Sigma} = \left(\mathbf{A}_0\mathbf{A}'_0\right)^{-1}$. As we can see, foreign variables are treated as predetermined in this block, i.e. it can be considered as a VARX model. In this case, coefficients $\mathbf{B}$ are estimated from (5) by OLS.

2.2.3 A compact form

The reduced form of the two models can be stacked into a single one, so that the SVAR model (3) can be estimated through standard methods. Thus, the model can be written as

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

where

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

As a result, the reduced form is now

$$\overrightarrow{\mathbf{y}}'_t = \overrightarrow{\mathbf{x}}'_t\overrightarrow{\mathbf{B}} + \overrightarrow{\mathbf{u}}'_t \quad \text{for } t = 1, \ldots, T; \tag{6}$$

where $\overrightarrow{\mathbf{B}} \equiv \overrightarrow{\mathbf{A}}_{+}\left(\overrightarrow{\mathbf{A}}_0\right)^{-1}$, $\overrightarrow{\mathbf{u}}'_t \equiv \overrightarrow{\varepsilon}'_t\left(\overrightarrow{\mathbf{A}}_0\right)^{-1}$, and $E\left[\overrightarrow{\mathbf{u}}_t\overrightarrow{\mathbf{u}}'_t\right] = \overrightarrow{\mathbf{\Sigma}} = \left(\overrightarrow{\mathbf{A}}_0\overrightarrow{\mathbf{A}}'_0\right)^{-1}$. In this case, if we estimate $\overrightarrow{\mathbf{B}}$ by OLS, this must be performed taking into account the block structure of the system imposed in matrices $\overrightarrow{\mathbf{A}}_i$, i.e. it becomes a restricted OLS estimation. Clearly, it is easier and more transparent to implement the two step procedure described above and, ultimately, since the blocks are independent by assumption, there are no gains from this joint estimation procedure (Zha, 1999). Last but not least, the lag length p is the same for both blocks and it is determined as the maximum obtained from the two blocks using the Schwarz information criterion (SIC).

2.3 SUR representation

Recall the linear model (5) and take the transpose, so that

$$\mathbf{y}_t = B'\mathbf{x}_t + \mathbf{u}_t$$

Then, following Koop and Korobilis (2010) use the $vec(.)$ operator, so that

$$\mathbf{y}_t = \left(\mathbf{x}'_t \otimes I_K\right) vec\left(B'\right) + \mathbf{u}_t$$

$$\mathbf{y}_t = Z_t\beta + \mathbf{u}_t$$

where $Z_t \equiv (\mathbf{x}'_t \otimes I_K)$ and β is a column vector with all the model coefficients. Then, using the entire sample $t = 1, \ldots, T$ we can write the VARX model as:

$$Y = Z\beta + U$$

such that $U \sim N(0, I \otimes \Sigma)$. As a result, the VARX system can be rewritten as a Normal linear regression model with a particular variance-covariance matrix for the error term, i.e. the SUR regression problem.

2.4 Priors and Posterior distribution

We adopt natural conjugate priors for the reduced form model parameters. The latter implies that the prior distribution, the likelihood function and the posterior distribution come from the same family of distributions (Koop and Korobilis, 2010). The introduction of priors is desirable, since the number of parameters to be estimated is very high and the number of observations is limited. Therefore, this a plausible strategy for reducing the amount of posterior uncertainty and, at the same time, it is useful for disciplining the data. In this regard, it is important to remark that we introduce priors for the reduced form coefficients, but this does not mean that we impose any prior information about the structural form. The latter is out of the scope of this paper, but more details can be found in Baumeister and Hamilton (2014) and Canova and Pérez Forero (2015).

We assume that the prior distribution of the object $\left(\mathbf{B}, \mathbf{\Sigma}^{-1}\right)$ is Normal-Wishart for each block separately. Since each block is going to be treated symmetrically, we only present the analytical distributions of the domestic block, so that

$$\beta \mid Y, \mathbf{\Sigma} \sim N\left(\underline{\beta}, \mathbf{\Sigma} \otimes \underline{V}\right)$$

$$\mathbf{\Sigma}^{-1} \mid Y \sim W\left(\underline{S}^{-1}, \underline{\nu}\right),$$

where $\underline{\beta} = vec\left(\underline{\mathbf{B}}\right)$ and $\left(\underline{\mathbf{B}}, \underline{V}, \underline{S}^{-1}, \underline{\nu}\right)$ are prior hyper-parameters with $\underline{\nu} = \tau$. In particular, we parametrize:

$$\underline{\beta} = \beta_{\tau}, \underline{S} = \underline{h}\Sigma_{\tau}, \quad \underline{V} = var(\beta_{\tau}),$$

with $\underline{h} = 1$ being a hyper-parameter, K the number of regressors in the model and β_{τ} is the OLS estimated coefficients using a training sample of τ observations. As a result, the posterior distribution is

$$\beta \mid Y, \mathbf{\Sigma} \sim N\left(\overline{\beta}, \mathbf{\Sigma} \otimes \overline{V}\right)$$

$$\mathbf{\Sigma}^{-1} \mid Y \sim W\left(\overline{S}^{-1}, \overline{\nu}\right),$$

where

$$\overline{V} = \left[\underline{V}^{-1} + \sum_{t=1}^{T} Z_t' \Sigma^{-1} Z_t \right]^{-1}$$

$$\overline{\beta} = \overline{V} \left[\underline{V}^{-1} \underline{\beta} + \sum_{t=1}^{T} Z_t' \Sigma^{-1} \mathbf{y}_t \right]$$

where $\overline{\beta} = vec\left(\overline{\mathbf{B}}\right)$ and

$$\overline{S} = \underline{S} + \sum_{t=1}^{T} \left(\mathbf{y}_t - Z_t \beta\right) \left(\mathbf{y}_t - Z_t \beta\right)'$$

$$\overline{\nu} = T + \underline{\nu}.$$

Given these analytical forms, we explain the next section how to obtain draws of $(\mathbf{B}, \mathbf{\Sigma})$ from the posterior distribution.

3 Bayesian Estimation

3.1 A Gibbs Sampling routine

Sampling from the posterior distribution of $\left(\overrightarrow{\beta}, \overrightarrow{\mathbf{\Sigma}}\right)$ is always difficult. However, in this case we have an analytical expression for each parameter block. Therefore it is possible to implement a Gibbs sampling routine. In this process, it is useful to divide the parameter set into different blocks.

The routine starts here. Set $k = 1$ and denote K as the total number of draws. Then follow the steps below:

1. Draw coefficients from the exogenous block $p\left(\beta^* \mid \mathbf{\Sigma}^*, \mathbf{y}^{*T}\right)$ and for domestic block $p\left(\beta \mid \mathbf{\Sigma}, \overrightarrow{\mathbf{y}}^T\right)$.

2. Construct $\overrightarrow{\beta} = \{\beta, \beta^*\}$ and compute the associated companion form. If the candidate draw is stable keep it, otherwise discard it.

3. Draw the covariance matrices through $p\left(\mathbf{\Sigma}^* \mid \beta^*, \mathbf{y}^{*T}\right)$ and $p\left(\mathbf{\Sigma} \mid \beta, \overrightarrow{\mathbf{y}}^T\right)$.

4. If $k < K$ set $k = k + 1$ and return to Step 1. Otherwise stop.

3.2 Estimation setup

For each country $n = 1, \ldots, N$ we run the Gibbs sampler for $K = 150,000$ and discard the first 100,000 draws in order to minimize the effect of initial values. Moreover, in order to reduce the serial correlation across draws, we set a thinning factor of 10, i.e. given the remaining 50,000 draws, we take 1 every 10 and discard the remaining ones. As a result, we have 5,000 draws for conducting inference. Priors are calibrated using a training sample for the span 1996:01-2007:07, i.e. the pre-crisis period, and then we estimate the model for the period 2007:08-2016:09. The latter is crucial since the structural shocks that aggregate economy is going to face in the short run are not necessarily comparable with the ones that were observed before the outbreak of the financial crisis. The specific details about the Data Description can be found in Appendix A.

4 Identification of structural shocks

4.1 Identification assumptions

The identification of monetary shocks is fairly standard. We have two types of restrictions, as it is displayed in Table 1. The first group is related with zero restrictions in the contemporaneous coefficients matrix, as in the old literature of Structural VARs, i.e. Sims (1980) and Sims (1986). In this case, as it is standard in the literature, we assume that the Economic Activity (GDP) and the Consumer Price Index (CPI) are slow variables, so that they do not react to monetary shocks contemporaneously. The second group are the sign restrictions as in Canova and De Nicoló (2002) and Uhlig (2005), where we set a horizon of six months.

In this case we assume that the monetary shock produces i) the typical liquidity effect, i.e. a negative response of money (M) after a contractionary shock and ii) a negative response of prices (CPI) and Economic Activity measured by the Industrial Production (GDP). Finally, we do not restrict the response of the Economic Policy Uncertainty Index (EPU) for the subsequent periods. Regarding demand shocks, we impose the the typical positive correlation between output and prices, and the latter is associated with higher interest rates in the future. Finally, for supply shocks we impose the standard trade-off assumption, i.e. while prices go up together with interest rates, output falls.

Var / Shock	Name	FFR shock	Demand shock	Supply shock
Domestic Block	$\mathbf{y}$	?	?	?
EPU index	EPU_{US}	?	?	?
IP growth	IP_{US}	$\leqslant 0$	$\geqslant 0$	$\leqslant 0$
CPI Inflation Rate	CPI_{US}	$\leqslant 0$	$\geqslant 0$	$\geqslant 0$
Federal Funds Rate	FFR	$\geqslant 0$	$\geqslant 0$	$\geqslant 0$
M1 Growth	$M1_{US}$	$\leqslant 0$	?	?
Commodity prices	$Pcom$	?	?	?
Oil prices	WTI	?	?	?

Table 1: Identifying Restrictions

The identification restrictions shown in Table 1 are only associated with a particular subset of shocks. As a result, the remaining shocks are unidentified. However, it turns out that this is not a econometric problem, since the literature of SVARs with sign restrictions explains that in order to conduct proper inference the model needs to be only partially identified (Rubio-Ramírez et al., 2010). Moreover, it deserves to be mentioned the fact that unlike Arias et al. (2016) we do not impose restrictions in the systematic component of monetary policy. On the other hand, we evaluate the dynamic response of aggregate variables assuming that other shock different from monetary policy can also generate a hike in interest rates. Thus, it is crucial and extremely important to make the explicit difference between monetary policy 'surprises' versus monetary actions predicted by the market because of other macroeconomic shocks.

4.2 The algorithm

In this stage we use as an input the estimation output from subsection 3.1, i.e. the posterior distribution of the reduced-form of the model. Then we take draws from this distribution as it is described in the following estimation algorithm[5]:

[5] See Uhlig (2005), among others.

1. Set first $K = 1,000$ number of draws.

2. Draw (β_k^*, Σ_k^*) from the posterior distribution (foreign block) and get $(\mathbf{A}_0^*)_k = (P^*)^{-1}$ from the *Cholesky* decomposition of $\Sigma_k^* = P^* (P^*)'$.

3. Draw $\mathbf{X}^* \sim N(0, I_{n^*})$ and get $\mathbf{Q}^*$ such that $\mathbf{Q}^*\mathbf{R}^* = \mathbf{X}^*$, i.e. an orthogonal matrix $\mathbf{Q}^*$ that satisfies the QR decomposition of $\mathbf{X}^*$. The random matrix $\mathbf{Q}^*$ has the uniform distribution with respect to the Haar measure on $O(n)$(Arias et al., 2014).

4. Construct the matrix:
$$\overline{\mathbf{Q}^*} = \begin{bmatrix} \mathbf{I}_{k^*} & \mathbf{0}_{(k^* \times n^* - k^*)} \\ \mathbf{0}_{(n^* - k^* \times k^*)} & \mathbf{Q}^* \end{bmatrix}$$
That is, a subset of $k^* < n^*$ variables in $(\mathbf{y}^*)$ are going to be *slow* and therefore they do not rotate. This how we impose zero restrictions in this case.

5. Draw (β_k, Σ_k) from the posterior distribution (domestic block) and get $(A_0)_k = (P)^{-1}$ from the *Cholesky* decomposition of $\Sigma_k = P(P)'$.

6. Draw $\mathbf{X} \sim N(0, I_n)$ and get $\mathbf{Q}$ such that $\mathbf{QR} = \mathbf{X}$, i.e. an orthogonal matrix $\mathbf{Q}$ that satisfies the QR decomposition of $\mathbf{X}$. The random matrix $\mathbf{Q}$ has the uniform distribution with respect to the Haar measure on $O(n)$(Arias et al., 2014).

7. Construct the matrix:
$$\overline{\mathbf{Q}} = \begin{bmatrix} \mathbf{I}_k & \mathbf{0}_{(k \times n - k)} \\ \mathbf{0}_{(n - k \times k)} & \mathbf{Q} \end{bmatrix}$$
That is, a subset of $k < n$ variables in $(\mathbf{y})$ are going to be *slow* and therefore they do not rotate. This how we impose zero restrictions in this case.

8. Compute the matrices $\overline{\mathbf{A}}_0 = (\mathbf{A}_0)_k \overline{\mathbf{Q}}$ and $\overline{\mathbf{A}^*}_0 = (\mathbf{A}_0^*)_k \overline{\mathbf{Q}^*}$, then recover the system (3) and compute the impulse responses.

9. If sign restrictions are satisfied, keep the draw and set $k = k + 1$. If not, discard the draw and go to Step 10.

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

5 Results

5.1 US Monetary Policy shocks

After simulating the posterior distribution of parameters and getting the structural shocks, now it is possible to assess the transmission mechanism of them to the aggregate economy. First, according to our identification strategy in Table 1, we put green lines in Figure 1 in order to indicate the restricted impulse responses. Because of the imposed sign restrictions, the tighter monetary policy produces a contraction in economic activity, as well as a decrease in the long to short term interest rates spread, money growth and inflation. Moreover, the increase in the FFR is very persistent, and this is because the initial point is very close to zero. The latter indicates that an initial orthogonal shock generates large effects that can be observed in the cumulative impacts. These results must be taken with caution, since we still have a considerable amount of uncertainty that can be materialized in the presented confidence intervals.

On the other hand, these results for the US are not surprising, since they are in line with most of the empirical macroeconomic literature. As a matter of fact, the beauty of the sign restrictions is the fact that they are far away from being controversial and are part of the conventional wisdom. All in all, we observe temporary real effects in line with the New Keynesian approach. The next step is to study the impact of these external monetary shock in the Latin American economies under study.

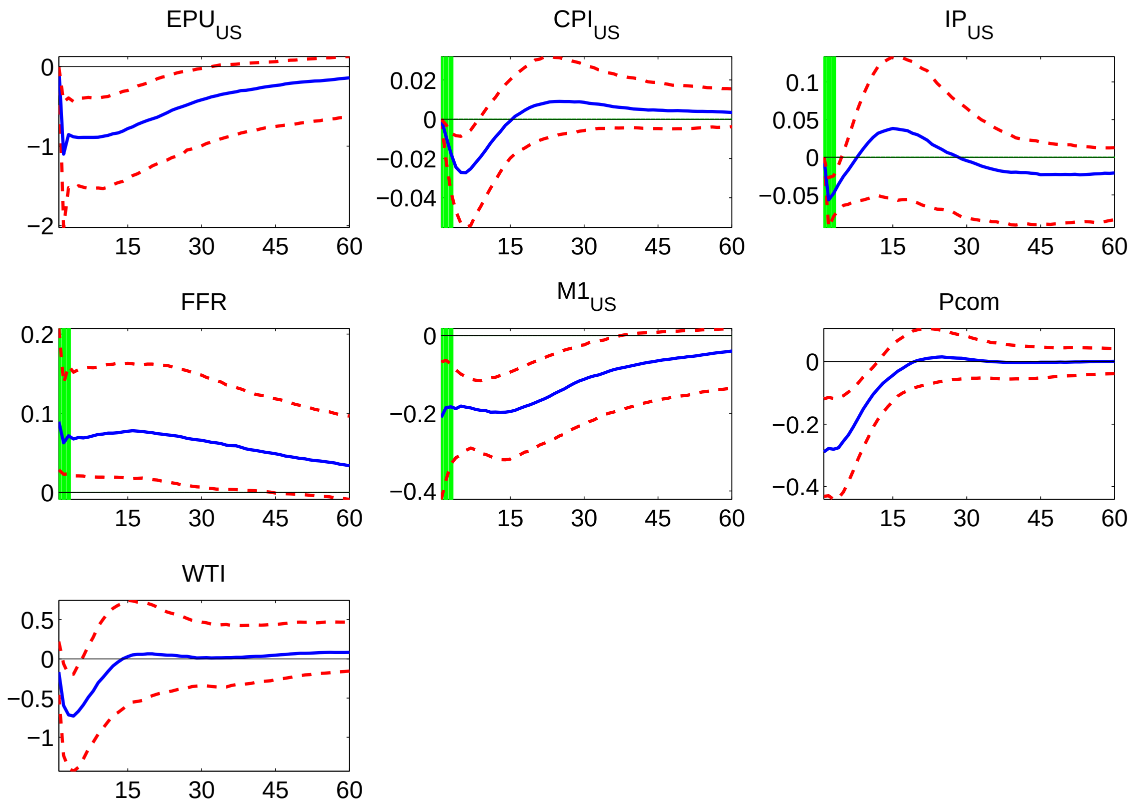

Figure 1: Response of U.S. variables after a Monetary policy shock; median value (solid line) and 68% bands (dotted lines)

Results in Figure 1 show that a US interest rate shock produces a medium run nominal depreciation and a positive reaction of the domestic interest rate in Latin American countries. Part of the explanation of this response of the exchange rate is the fact that there exists Foreign Exchange Intervention by the Central Bank. In general, this could also be related with the presence of the *Delayed overshooting puzzle*.

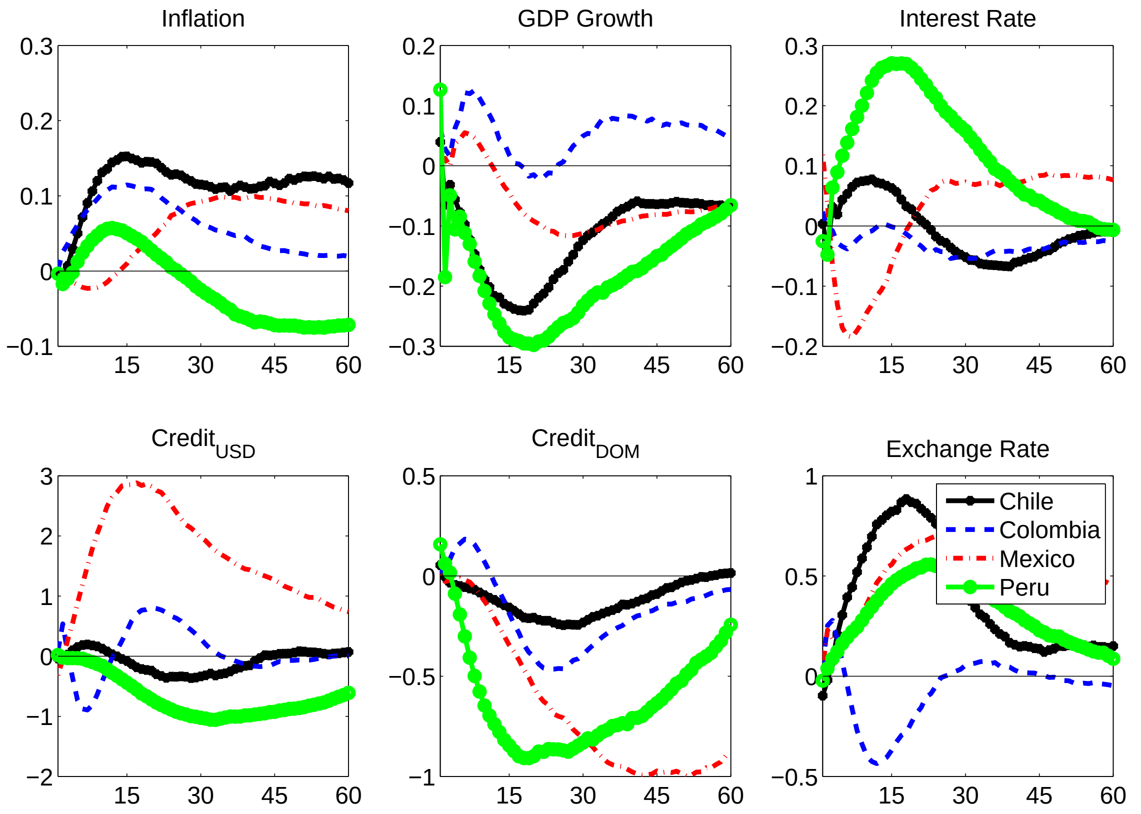

Figure 2: Response of LATAM variables after a US Monetary policy shock; median values

Moreover, the tighter external monetary policy produces, in most cases, a negative effect in aggregate credit in domestic currency, a negative effect in economic activity and a positive effect in inflation. Nevertheless, our results cannot be directly compared with Canova (2005), since it should be noticed that we take into account the Unconventional Monetary Policy (UMP) period when performing the estimation. In addition, some differences can be observed across country impulse responses. In particular, the response of the depreciation rate is more persistent in Chile, Mexico and Peru rather than in Colombia.

5.2 US Demand shocks

A positive demand shock is identified by imposing the following restrictions: the economic activity and the inflation rate must respond positively and in the same direction. As result, following a typical Taylor rule effect, the interest rate goes up. That is, a typical IS shock that impacts on aggregate demand, and has a subsequent effect on inflation. This is one of the reasons why the Fed may consider raising the FFR, since it would be in line with the idea that the US economy is in a good state, and in the long rung this could be also reflected in a higher inflation rate. In general, it is far from controversial that after a demand shock the Fed is likely to increase the interest rate, and this what we observe in Figure 3.

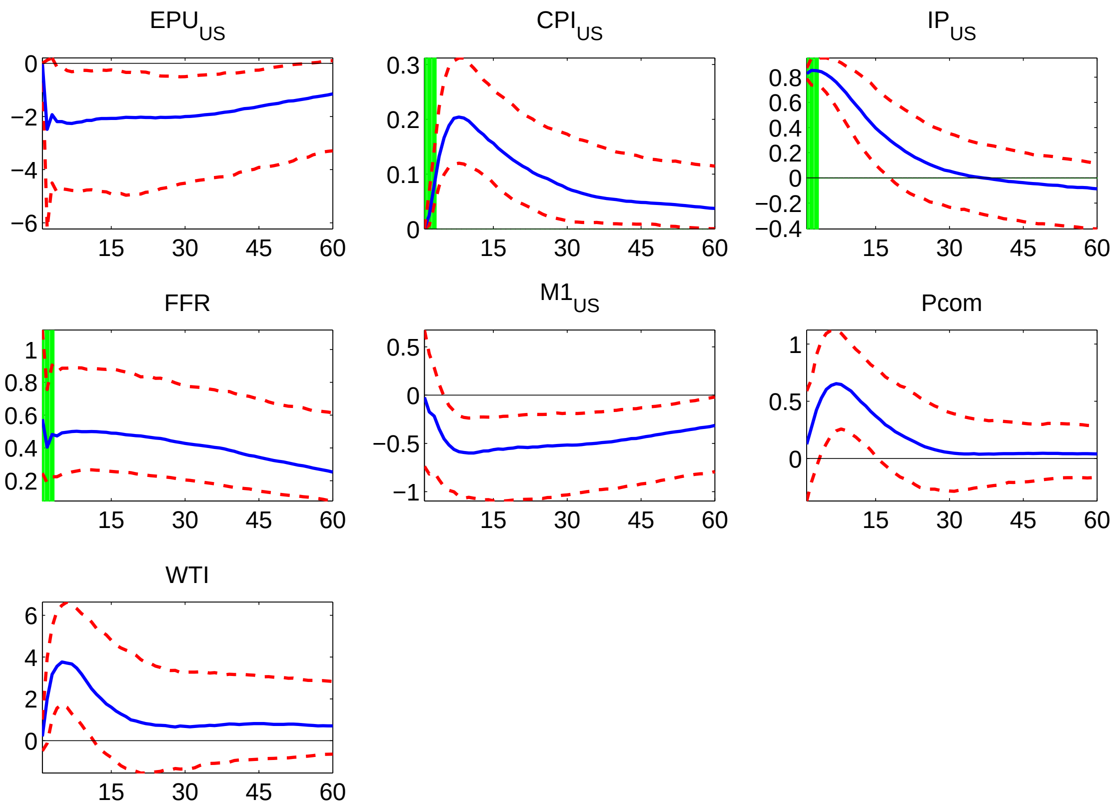

Figure 3: Response of U.S. variables after a demand shock; median value (solid line) and 68% bands (dotted lines)

The identified shock is then transmitted to the Latin American Economies. Unlike monetary policy shocks, demand shocks do not produce higher inflation and they on average produce a fall in GDP and the domestic interest rate. Finally, these demand shocks produce a fall in domestic currency credit and an appreciation of the domestic currency. As a consequence, we have evidence that suggest that depending on the causes that motivate a raise in US interest rates, the structural effects will differ completely. In this case, a demand shock reflects better economic conditions for the US, which also implies a depreciation of the dollar, which provokes an expansion of foreign currency credit.

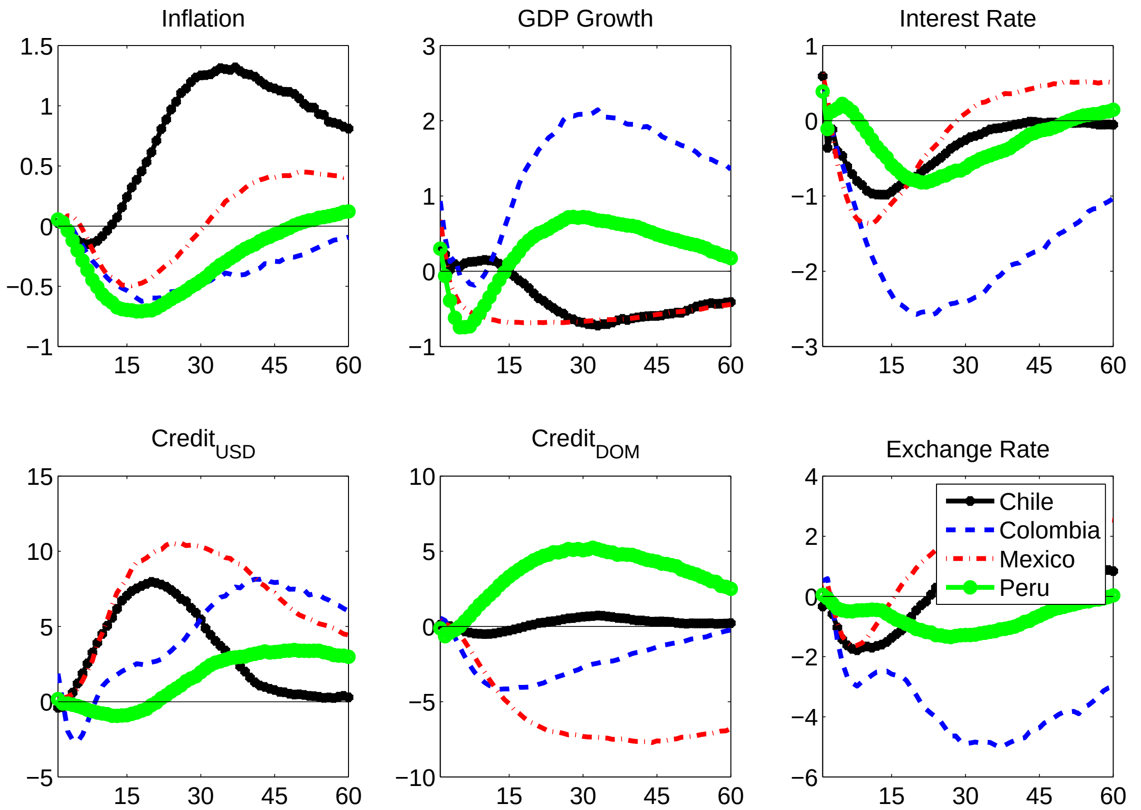

Figure 4: Response of LATAM variables after a US demand shock; median values

5.3 US Supply shocks

A supply shock is identified by imposing the following: economic activity and inflation must respond in opposite directions. That is, a typical Phillips Curve shock that impacts on aggregate supply, and has a subsequent effect on inflation, and produces a negative effect on output. This is another the reason why the Fed may consider moving the FFR, since it would be in line with the idea that the US economy is in a bad state, but at the same time this could be reflected in more inflation. In general, it is far from clear that after a supply shock the Fed is likely to increase the interest rate, and this what we observe in Figure 5.

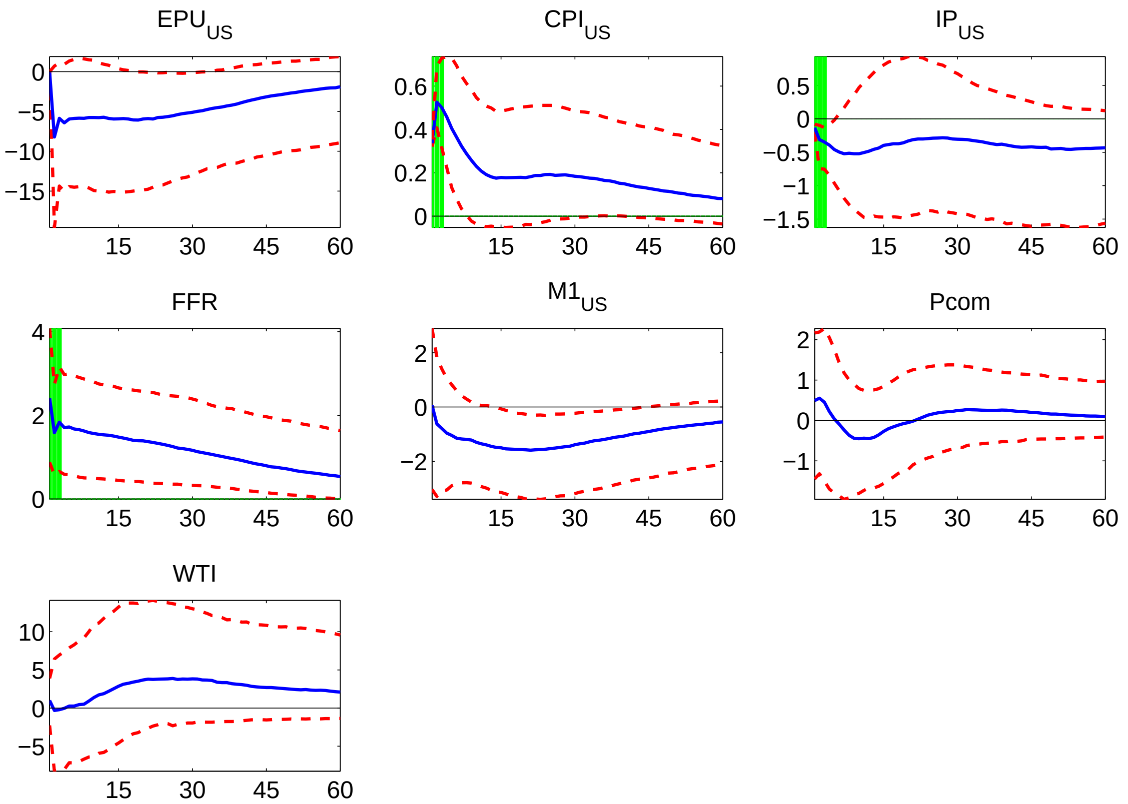

Figure 5: Response of U.S. variables after a supply shock; median value (solid line) and 68% bands (dotted lines)

The next step is to measure the impact of this shock on Latin American Economies. We do not find much significant spillover effects for the four economies (see appendix B.3). That is, in general we observe a considerable uncertainty related with the effects of these shocks, which means that these shocks are not present in the data for the period of analysis. Perhaps more work is needed in terms of imposing more restrictions to properly identify supply shocks, since it is widely accepted in the literature that sign restrictions are relatively weak. On the other hand, given the reduced span of data (2007-2016), it is natural to observe a considerable amount of uncertainty, and this could be fixed by considering tighter priors.

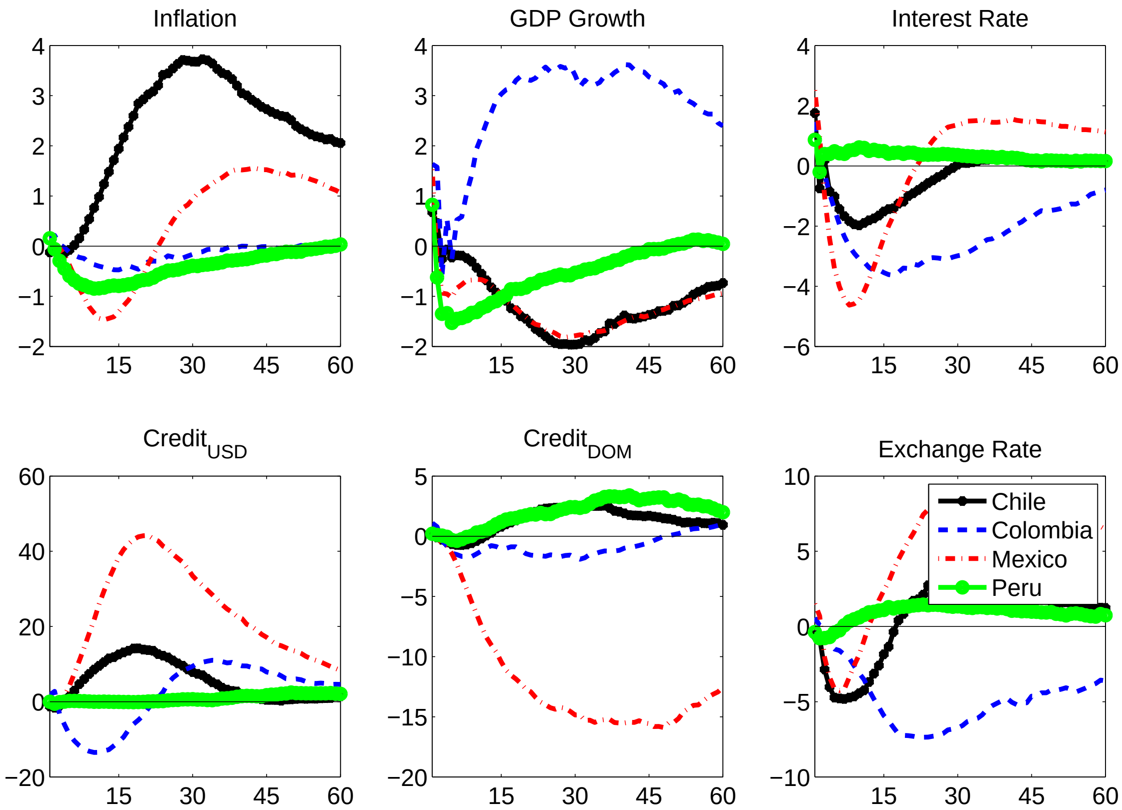

Figure 6: Response of LATAM variables after a US supply shock; median values

6 Concluding Remarks

We have estimated the potential effect in Latin American Economies of a normalization in the US monetary policy. Results are mixed across different economies and must be taken with caution. The increase in the FFR is very persistent, and this is because the initial point is very close to zero. Moreover, it produces the usual liquidity effect, a contraction in US economic activity and a decrease in the CPI inflation. Second, demand shocks trigger a rise in US interest rate and finally supply shocks reduce the US interest rate. Both effects are in line with a predictable monetary policy.

Regarding Latin American economies, we study the case of Chile, Colombia, Mexico and Peru. Given the considerable amount of uncertainty regarding the effect these shocks, we use Bayesian techniques in order to properly assess the confidence intervals of the associated impulse responses. Results show that a US interest rate shock produces a nominal depreciation and a positive reaction of the domestic interest rate. Furthermore, in most cases the identified external monetary shock affects negatively in aggregate credit (in both currencies), economic activity and inflation. On the other hand, demand and supply shocks have mixed and uncertain effects across LATAM economies. Perhaps more work is needed in terms of imposing more restrictions to properly identify both demand and supply shocks, since it is widely accepted in the literature that sign restrictions are relatively weak. On the other hand, given the reduced span of data (2007-2016), it is natural to observe a considerable amount of uncertainty, and this could be fixed by considering tighter priors.

Overall, in terms of the the contribution of the paper, we use an efficient approach in order to assess the spillover effects of US Monetary Policy Normalization in LATAM economies from the data, an event that is still a current issue for Latin American Policy makers, especially for Central Banks. This is not an easy task and deserves more attention in the literature. Our approach is flexible relative to a stylized dynamic macroeconomic model, and this is why there exists some space to do some refinements. This could take the direction of expanding the information set and also considering additional plausible restrictions. Nevertheless, so far we consider that we have imposed enough restrictions in order to properly identify and isolate the three structural shocks mentioned in this document.

A Data Description

We include monthly data for the period January 1996 - September 2016 with the exception of Colombia, where the sample stops at June 2014.

A.1 Big economy block variables $\mathbf{y}_t^*$

We include the following variables for the exogenous block:

- Economic Policy Uncertainty index from the U.S. (EPU_{US}).
- Consumer Price Index for All Urban Consumers: All Items (1982-84=100), not seasonally adjusted.
- Industrial Production Index (2007=100), seasonally adjusted.
- Federal Funds Rate (FFR)[6].
- M1 Money Stock, not seasonally adjusted.
- Producer Price Index (All Commodities).
- Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma.

Data is in monthly frequency (1996:01-2016:09) and it was taken from the Federal Reserve Bank of Saint Louis website (FRED database).

A.2 Chilean Economy block variables ($\mathbf{y}_t$)

We include the following variables from the Chilean economy:

- Nominal exchange rate.
- Interbank interest rate in Chilean pesos.
- Aggregated credit of the banking system in U.S. Dollars (Foreign Currency).

[6]We include the Shadow Interest Rate as in Wu and Xia (2015) starting in 2008.

- Aggregated credit of the banking system in Chilean pesos (Domestic Currency).
- Consumer price index (2008=100).
- IMACEC Monthly indicator of economic activity (2008=100), not seasonally adjusted.

Data is in monthly frequency (1996:01-2016:09) and it was taken from the Central Bank of Chile website. All variables except interest rates are included as year-to-year growth rates.

A.3 Colombian Economy block variables ($\mathbf{y}_t$)

We include the following variables from the Colombian economy:

- Nominal exchange rate.
- Interbank interest rate in Colombian pesos.
- Aggregated credit of the banking system in U.S. Dollars (Foreign Currency).
- Aggregated credit of the banking system in Colombian pesos (Domestic Currency).
- Consumer price index (December 2008=100).
- Real industrial production index (1990=100), not seasonally adjusted.

Data is in monthly frequency (1996:01-2014:06) and it was taken from the Banco de la República website. All variables except interest rates are included as year-to-year growth rates.

A.4 Mexican Economy block variables ($\mathbf{y}_t$)

We include the following variables from the Mexican economy:

- Nominal exchange rate.
- Interbank interest rate (at 28 days) in Mexican pesos.
- Aggregated credit of the banking system commercial banks) in U.S. Dollars expressed in Mexican pesos (Foreign Currency).

- Aggregated credit of the banking system (commercial banks) in Mexican pesos (Domestic Currency).
- Consumer price index (December 2010=100).
- IGAE Global economic activity index (2008=100), not seasonally adjusted.

Data is in monthly frequency (1996:01-2016:09) and it was taken from the Banco de México website. All variables except interest rates are included as year-to-year growth rates.

A.5 Peruvian Economy block variables ($\mathbf{y}_t$)

We include the following variables from the Peruvian economy:

- Nominal exchange rate index.
- Interbank interest rate in Soles (in percentages).
- Aggregated credit of the banking system in U.S. Dollars (Foreign Currency).
- Aggregated credit of the banking system in Soles (Domestic Currency).
- Consumer price index for Lima (2009=100).
- Real Gross Domestic Product index (2007=100), not seasonally adjusted.

Data is in monthly frequency (1996:01-2016:09) and it was taken from the Central Reserve Bank of Peru website. All variables except interest rates are included as year-to-year growth rates.

B Impulse responses

B.1 Spillover effects from US Monetary Policy shocks

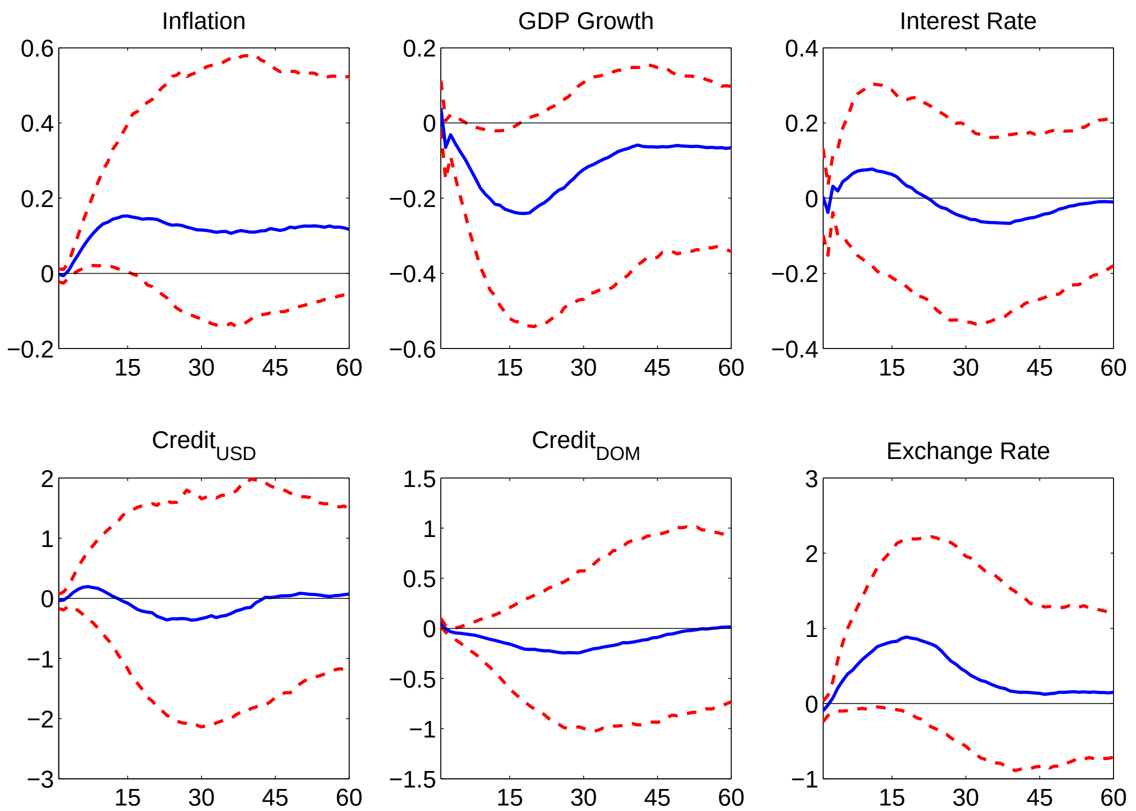

Figure 7: Response of Chilean variables after a US Monetary Policy shock; median value and 68% bands

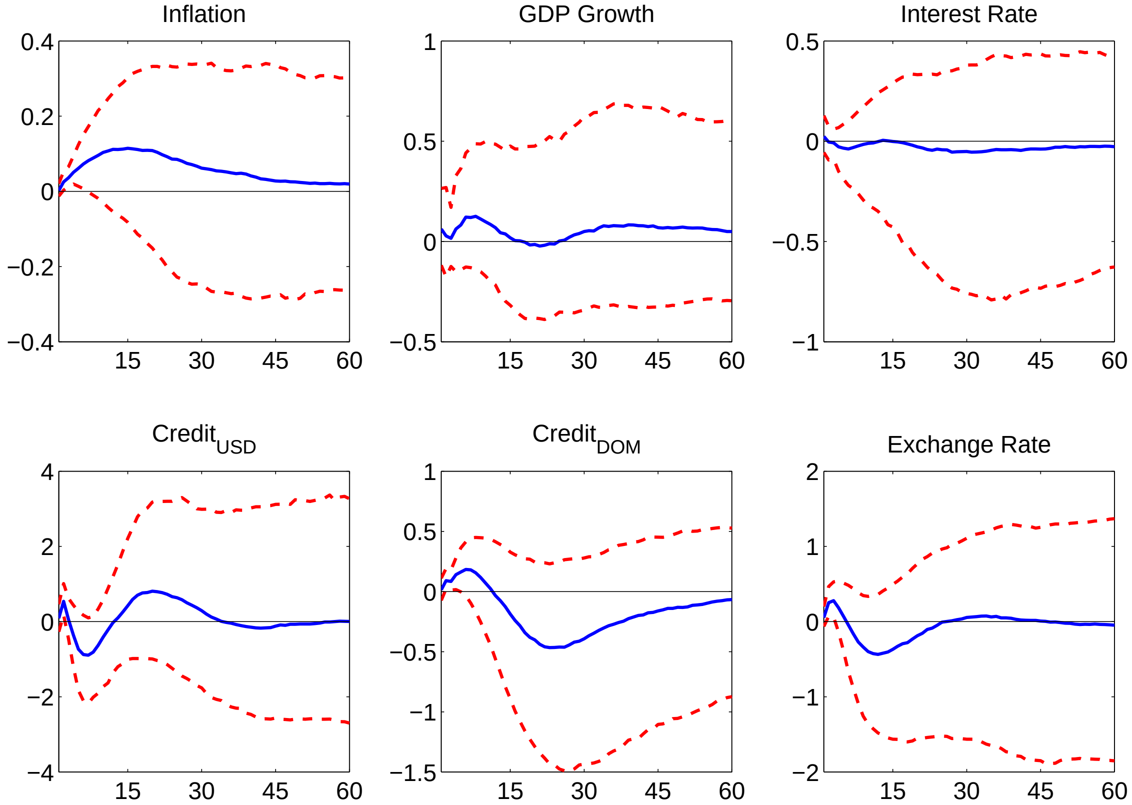

Figure 8: Response of Colombian variables after a US Monetary Policy shock; median value and 68% bands

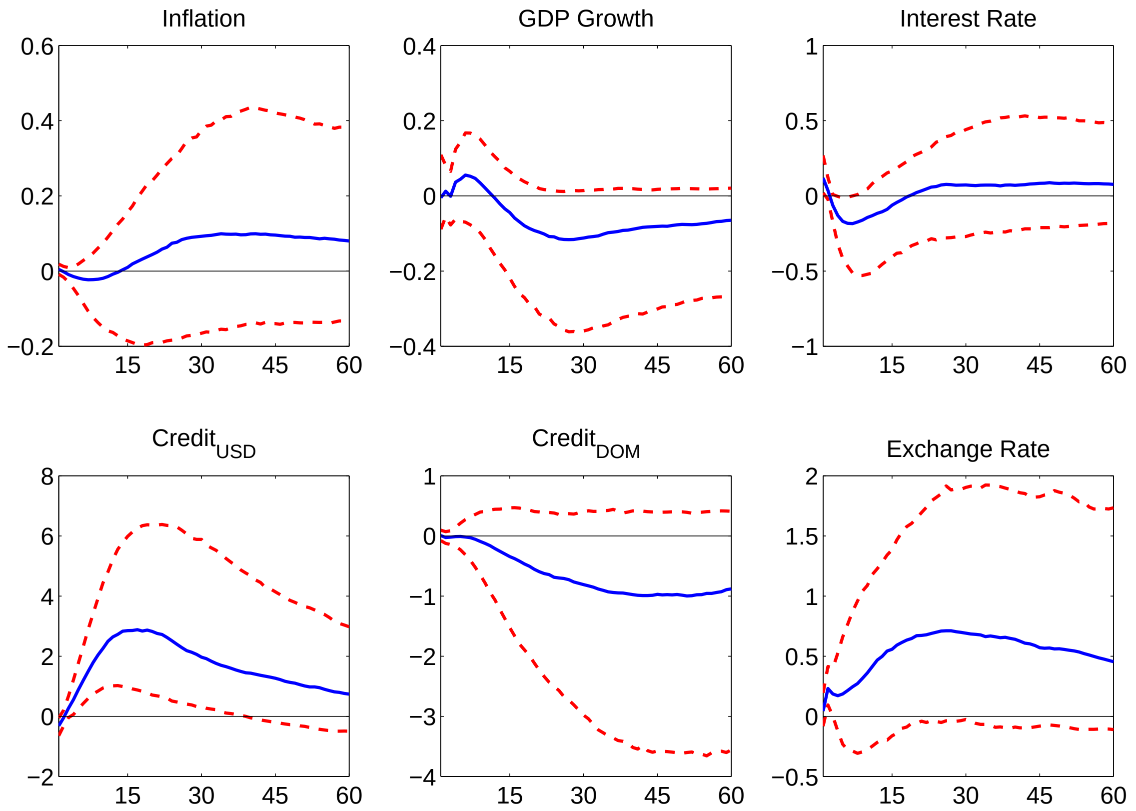

Figure 9: Response of Mexican variables after a US Monetary Policy shock; median value and 68% bands

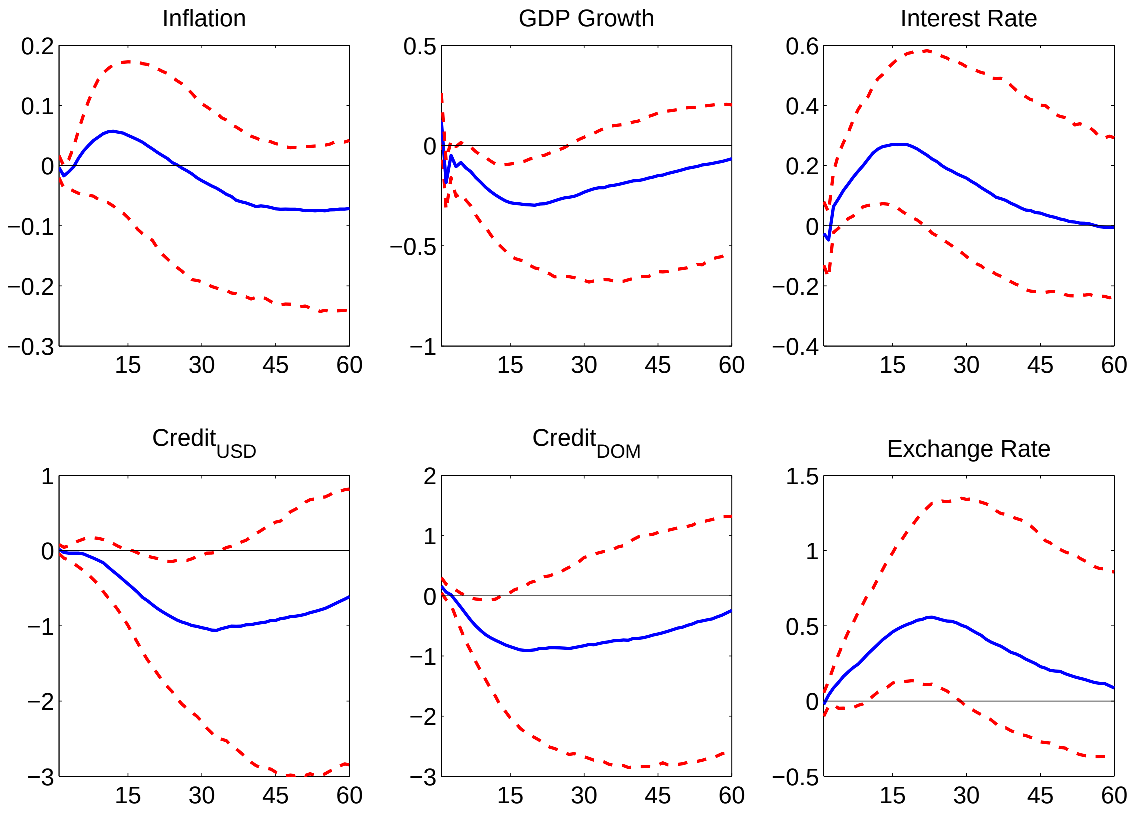

Figure 10: Response of Peruvian variables after a US Monetary Policy shock; median value and 68% bands

B.2 Spillover effects from US Demand shocks

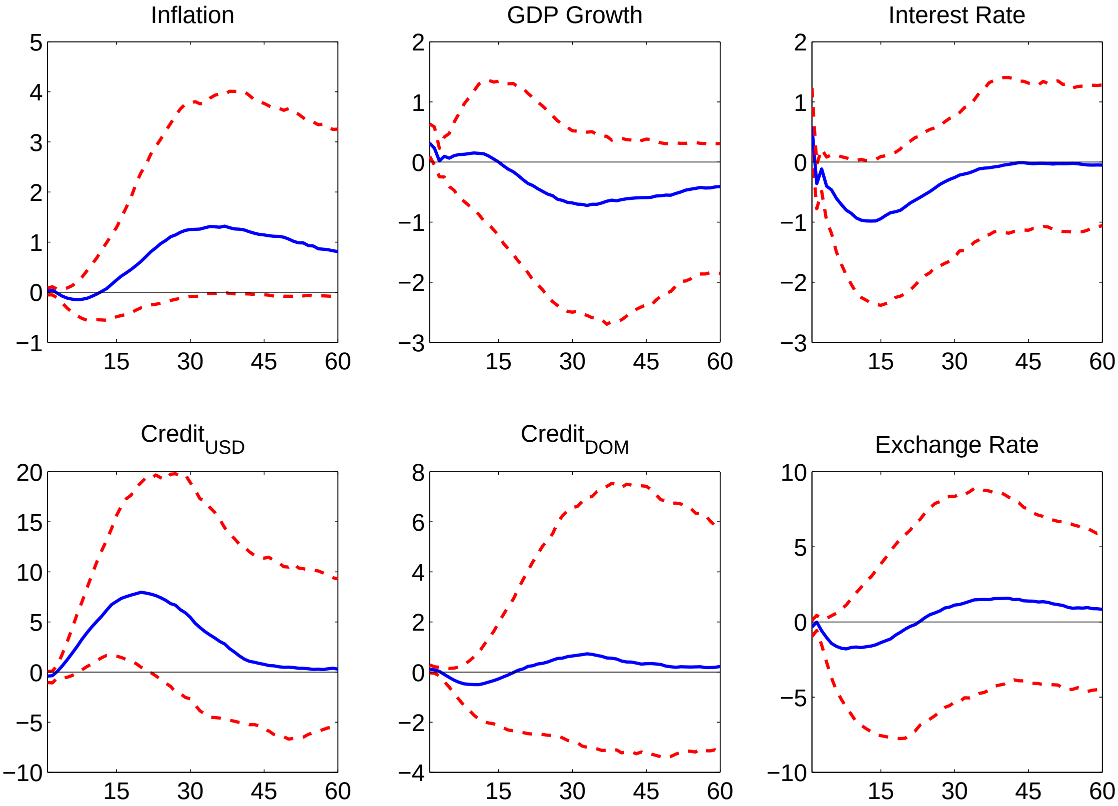

Figure 11: Response of Chilean variables after a US demand shock; median value and 68% bands

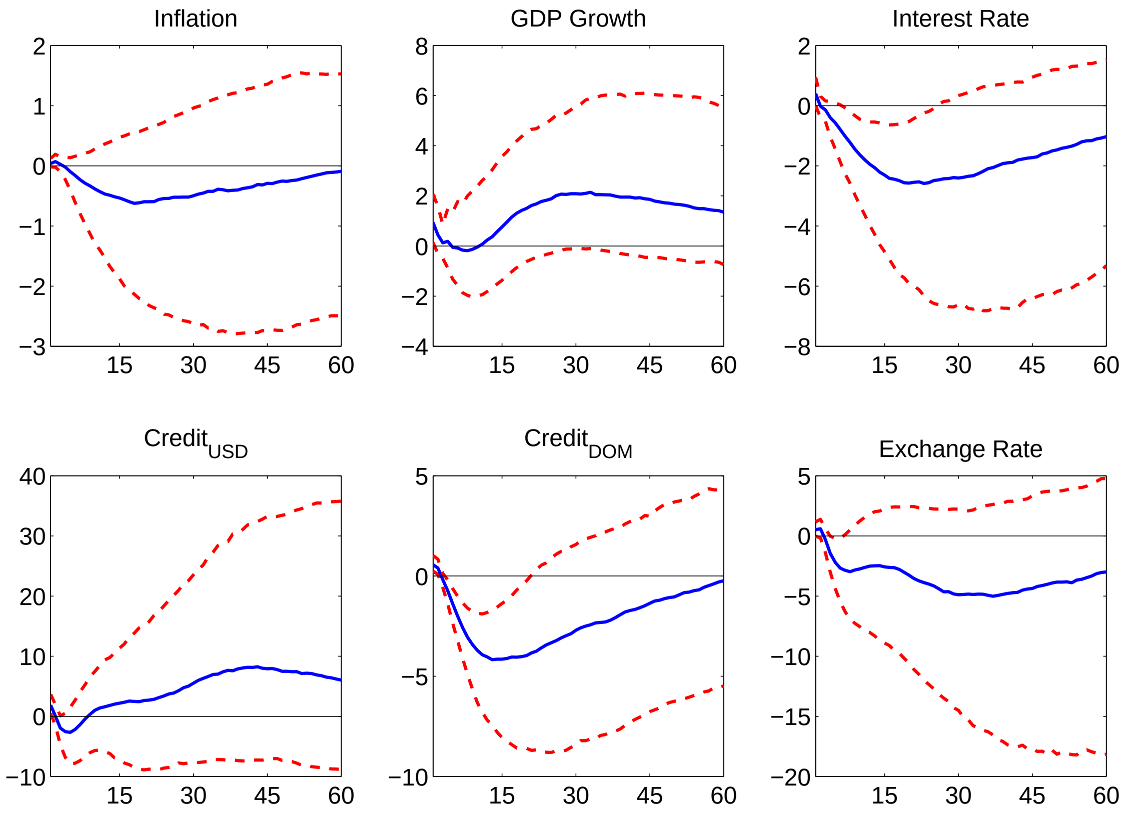

Figure 12: Response of Colombian variables after a US demand shock; median value and 68% bands

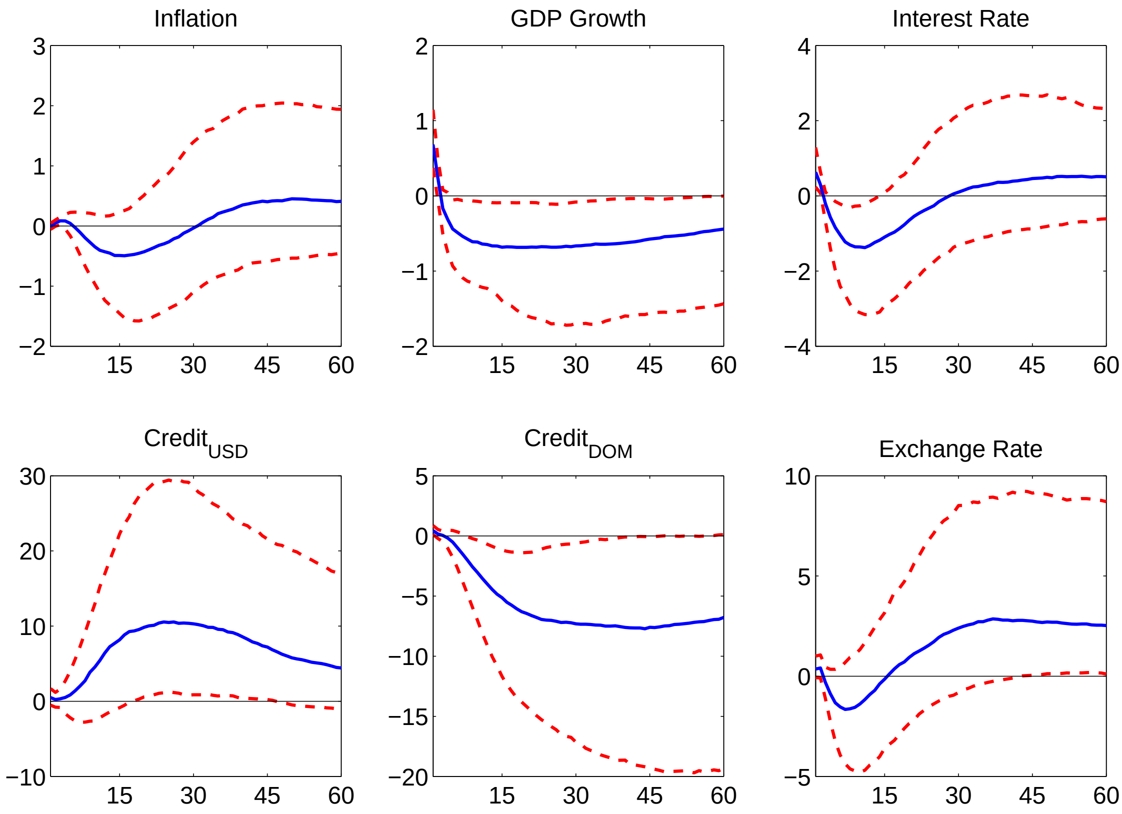

Figure 13: Response of Mexican variables after a US demand shock; median value and 68% bands

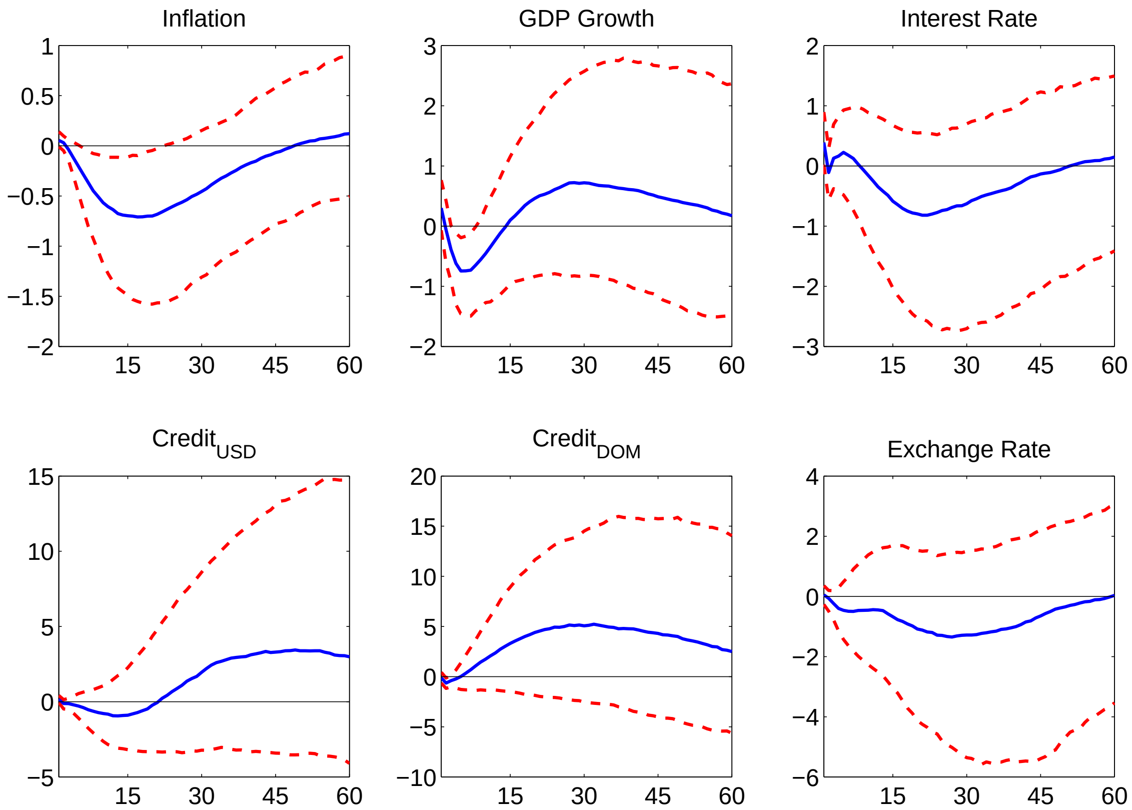

Figure 14: Response of Peruvian variables after a US demand shock; median value and 68% bands

B.3 Spillover effects from US Supply shocks

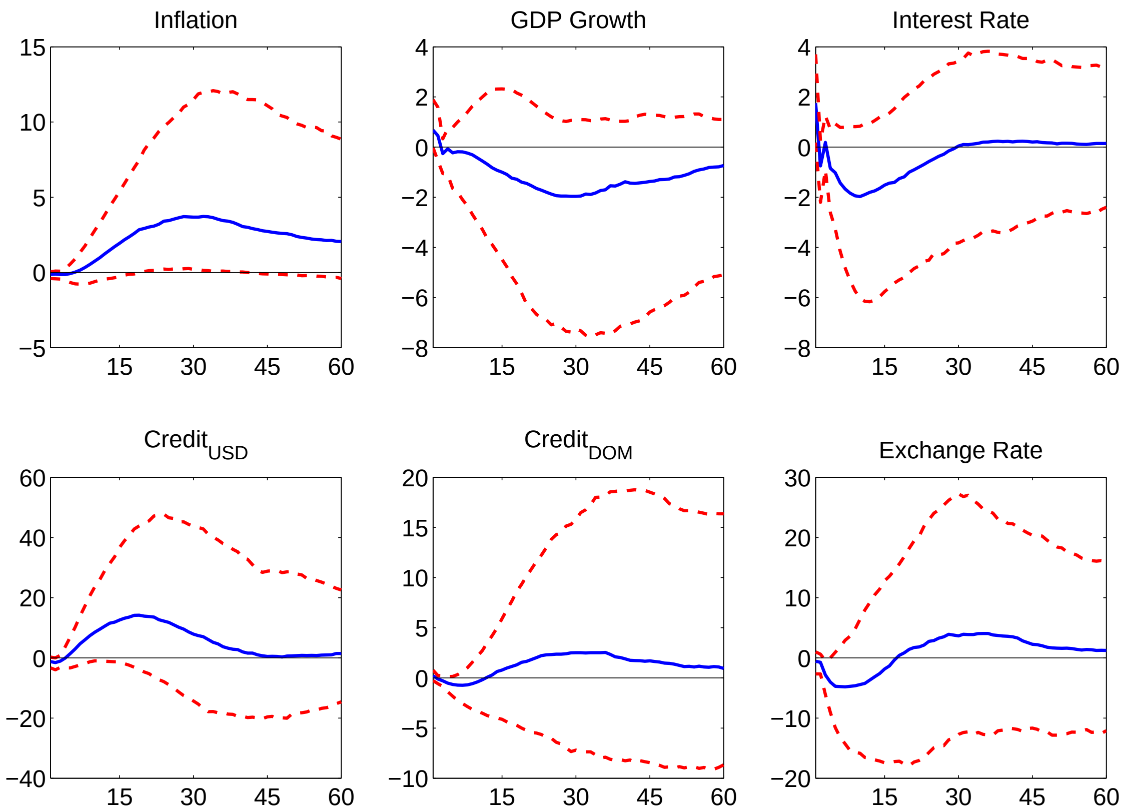

Figure 15: Response of Chilean variables after a US supply shock; median value and 68% bands

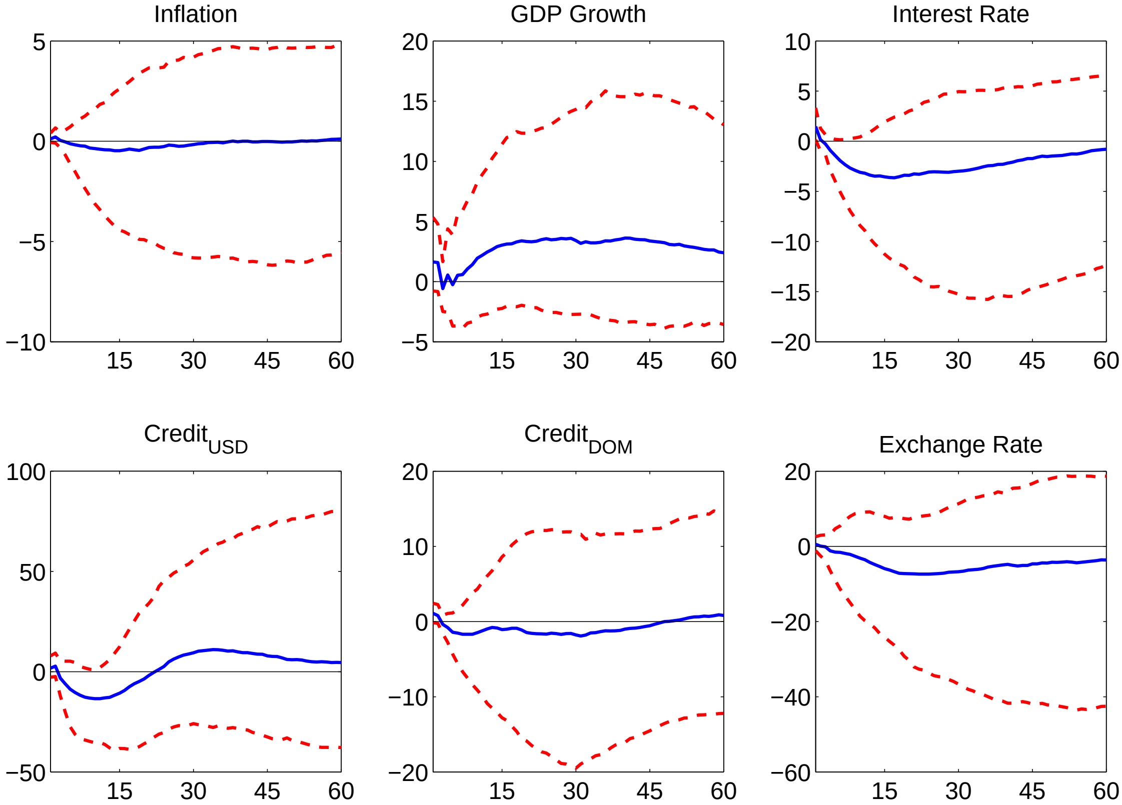

Figure 16: Response of Colombian variables after a US supply shock; median value and 68% bands

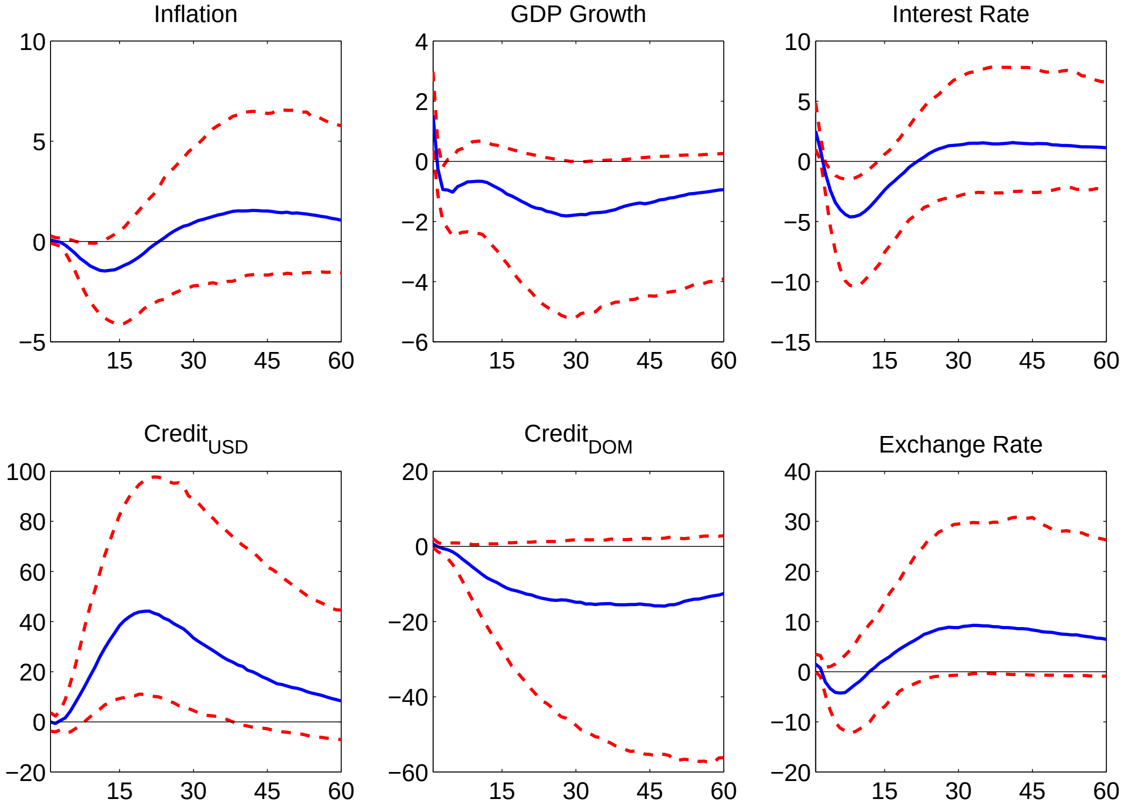

Figure 17: Response of Mexican variables after a US supply shock; median value and 68% bands

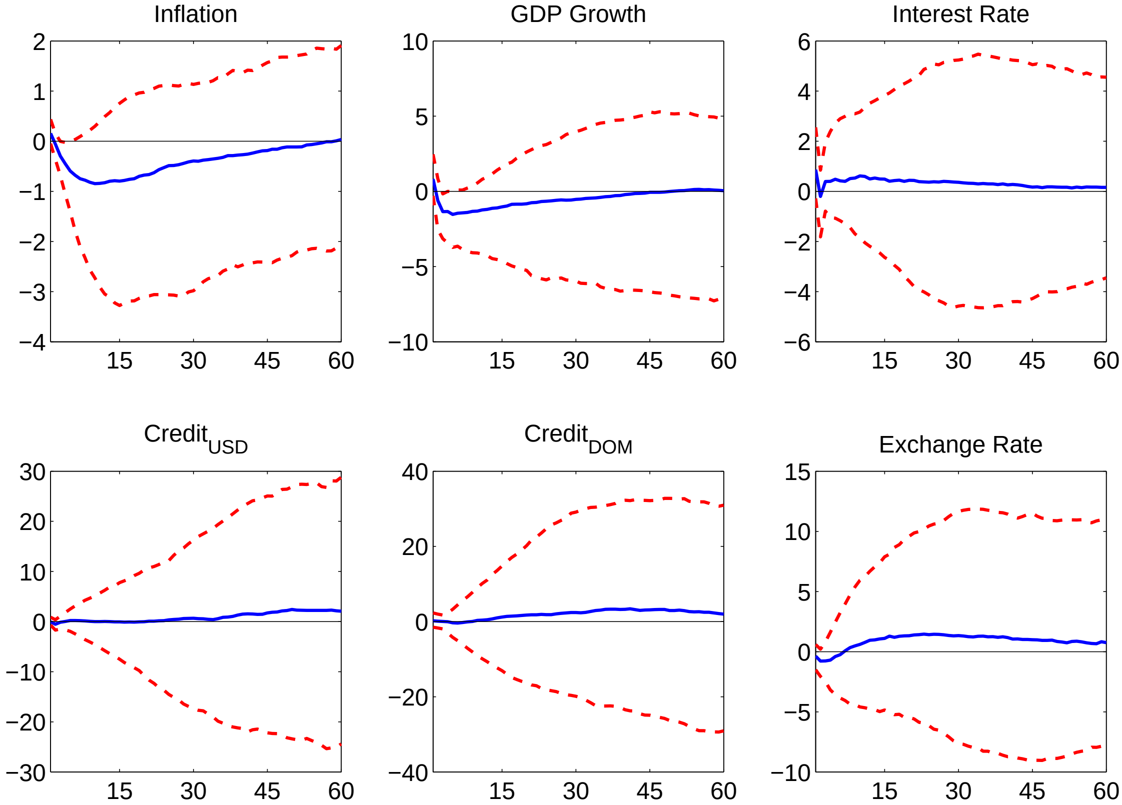

Figure 18: Response of Peruvian variables after a US supply shock; median value and 68% bands

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