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EFFECTS OF US QUANTITATIVE EASING ON LATIN AMERICAN ECONOMIES

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Most emerging economies have been affected to some degree by the Fed's quantitative easing (QE) policies. This paper assesses the impact of these measures in terms of key macroeconomic variables for four inflation-targeting small open economies in Latin America. We identify a QE policy shock in a structural vector autoregressive with block exogeneity and a mixture of zero and sign restrictions. Overall, we find that these QE policies have significant effects on financial variables such as the exchange rate, and these effects are larger with respect to those in output and prices. Furthermore, the effects vary across countries, and these are more significant in Chile and Mexico than in Peru and Colombia.

Keywords: Quantitative easing, Structural vector autoregressions, Sign and zero restrictions

1. INTRODUCTION

There has been widespread concern among policymakers in emerging economies about the effects of the quantitative easing (QE) policies implemented in developed economies, given that these measures have triggered large surges in capital inflows to emerging countries, leading to exchange rate appreciation, high-credit growth, and asset price booms. However, it is unclear whether these effects are transmitted to economic activity and inflation, and, if they are, what their propagation mechanism is. This is related to the fact that most central banks

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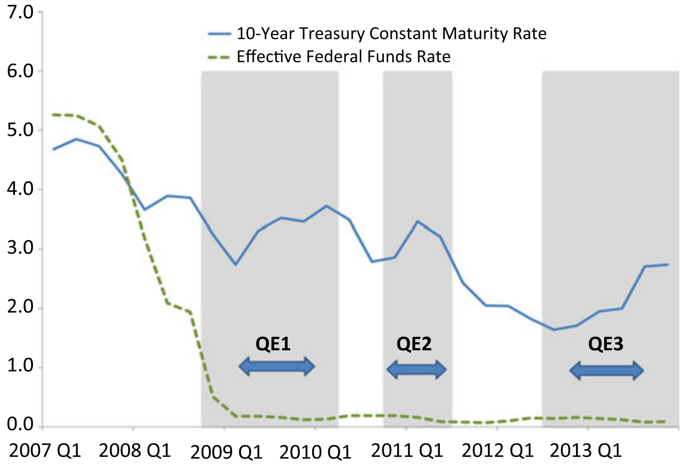


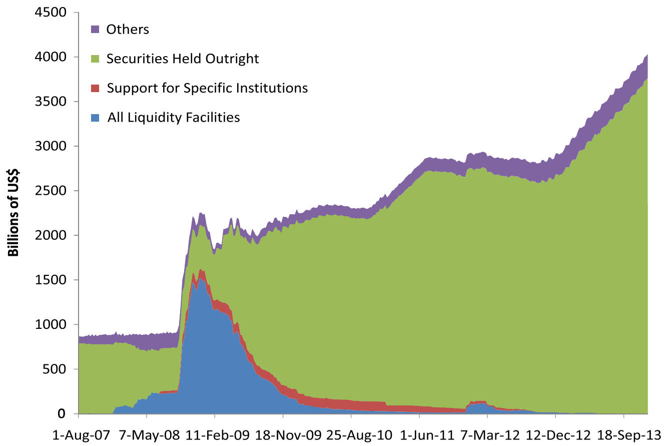
Source: Federal Reserve Economic Database (FRED).

FIGURE 1. Long- and short-term interest rates.

in emerging economies have implemented macroprudential policies with the purpose of mitigating any potential systematic risk.

Unconventional monetary policy measures are implemented in developed countries with the purpose of stimulating economic activity, since standard monetary policies have become ineffective (the short-term interest rate has reached its zero lower bound (ZLB)). Walsh (2010) points out that central banks do not directly control the money supply, inflation, or long-term interest rates, likely to be most relevant for aggregate spending; however, they can have close control over narrow reserve aggregates, such as the monetary base or a short-term interest rate. Those operating procedures—the relationship between central bank instruments and operating targets—are crucial for the implementation of a QE policy.

QE policy measures implemented by the Fed result in an increase in private-sector liquidity, mainly through the purchase of long-term securities. That is, the QE episode in the USA was characterized by a sharp increase in the size of the Fed balance sheet, together with an increase in money aggregates, a decrease in the interest rate spread, and a short-term interest rate close to zero. Figure 1 shows the policy rate close to zero starting in 2009 and, at the same time, how the spread between long- and short-term interest rates decreases. Figure 2 shows the evolution of the Fed's balance sheet components; in particular, it illustrates the switch toward securities—especially mortgage-backed securities (MBS) and long-term treasury bonds—in early November 2008. If the aggregate demand depends on long-term interest rates, then special factors that reduce the spread between short- and long-term rates will stimulate the economy; and if the term premium declines, then a higher short-term rate is required to obtain consistent financial conditions with maximum sustainable employment and stable prices [Bernanke (2006)].



Source: Federal Reserve Economic Database (FRED).

FIGURE 2. Fed's balance sheet.

Starting in 2009, the central banks in the USA, the UK, Canada, Japan, and the Euro area reduced their policy rates to close to the ZLB. At the same time, these institutions used alternative policy instruments and adopted macroprudential measures that focused on close monitoring and supervision of financial institutions. Financial stability became one of the main policy targets. Expansion of central bank balance sheets through purchases of financial securities and announcements about future policy (influencing expectations) became the standard approach.[1]

Jones and Kulish (2013), Hamilton and Wu (2012), and Taylor (2011) analyze the effects of QE policy on the global economy. However, most of these researchers focus on financial variables such as long-term interest rates and aggregate bank lending credit. In turn, other authors analyze the QE policy effects on other key macroeconomic variables within a single economy: Glick and Leduc (2012) and Jawadi et al. (2017) study the case of the USA; Lenza et al. (2010) and Peersman (2011) analyze the Euro area; and Schenkelberg and Watzka (2013) cover the case of Japan. Gambacorta et al. (2014) perform a similar analysis for eight advanced countries. Belke and Klose (2013) study the spillover effects between the USA and the Euro area. Baumeister and Benati (2013) quantify the QE policy effects in the USA and in the UK. Finally, Curdia and Woodford (2011) and Céspedes et al. (2017) take a theoretical approach to the effects of these policies and their implications for open economies.

On the other hand, central banks from developing countries took into account most of the effects of QE and adopted their own macroprudential policies. Because the links between the macroeconomy and financial markets have changed, policymakers have to deal with a new environment in which there are two policy stability objectives: macroeconomic and financial. Following the Tinbergen principle, a policymaker requires two instruments for two policy objectives. For most Latin American countries within an inflation-targeting framework, this means a policy interest rate and a macroprudential tool.[2]

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In the case of our sample, the purpose of these policies varies significantly across countries. In general, they are intended to affect financial variables such as exchange rates, capital flows, credit markets, and asset prices. However, these macroprudential policies have been adopted at differing speeds and times, and are subject to different preferences in terms of frequency of intervention and willingness to use.[3] The management of reserve requirements (both in domestic and foreign currencies) and exchange rate volatility has been key for achieving a stabilized financial sector in Peru because of the borrowing carried out by firms in foreign currency. On the other hand, the financial sectors of Chile and Mexico avoid excessive impacts, because in previous years, most activity involved implementation of Basel III-type regulatory policies.[4]

One branch of the literature has analyzed the effectiveness of unconventional monetary policy measures taken by central banks in advanced and emerging economies alike. In particular, policymakers are interested in assessing the impact of QE policies on output and inflation. As to methodology, studies of QE policies using structural vector autoregressive (SVAR) models with zero and sign restrictions include Schenkelberg and Watzka (2013) and Baumeister and Benati (2013) for the case of the USA and the UK. However, little research has been conducted in regard to the spillover effects of these policy measures on emerging market economies.[5]

This paper focuses on the QE policy measures implemented by the Fed, and their macroeconomic effects on four Latin American economies: Chile, Colombia, Mexico, and Peru. This group of small open economies (SOEs) shares certain characteristics, such as application of an inflation-targeting scheme, issuance of credit in both domestic and foreign currency, and receipt of major capital inflows. These shared characteristics give us more confidence in the process of identifying what we call a QE policy shock.

To identify the QE shock from the USA, we estimate an SVAR model with block exogeneity, in the spirit of Zha (1999), and identify this shock through a mixture of zeros and sign restrictions, in line with Arias et al. (2018). Having identified the shock, we assess how it is transmitted to each SOE. The advantage of our approach is that, by construction, US shocks can affect each SOE, but not the other way around. In this sense, the structure of the paper is as follows: Section 2 presents the SVAR model with block exogeneity; Section 3 discusses the identification of the QE shock; Section 4 presents the estimation results; and Section 5 concludes.

2. AN SVAR MODEL WITH BLOCK EXOGENEITY

In this section, we closely follow Cushman and Zha (1997) and Zha (1999). They argue that block exogeneity in an SVAR is a natural extension for SOEs, since it rules out any unrealistic effects that could arise in a standard SVAR model, for example, a significant effect on the big economy caused by a shock in the small one. Furthermore, the assumption of block exogeneity greatly reduces the number of parameters to be estimated. In this section, we model with Bayesian techniques.

2.1. The Setup

Consider a two-block SVAR model. We take this standard specification in order to correctly assemble into an SOE setup. In this context, the big economy is represented 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 $\mathbf{y}_t^*$ is an $n^* \times 1$ vector of endogenous variables; ε_t^* is an $n^* \times 1$ vector of structural shocks in which $\varepsilon_t^* \sim N(0, I_{n^*})$; $\mathbf{A}_i^*$ is an $n^* \times n^*$ matrix of structural parameters for $i = 0, \ldots, p$; $\mathbf{w}_t$ is an $r \times 1$ vector of exogenous variables; $\mathbf{D}^*$ is an $r \times n^*$ matrix of structural parameters; and p is the lag length.

The SOE is represented by

$$\mathbf{y}_t^{\prime}\mathbf{A}_0 = \sum_{i=1}^{p}\mathbf{y}_{t-i}^{\prime}\mathbf{A}_i + \sum_{i=0}^{p}\mathbf{y}_{t-i}^{*\prime}\widetilde{\mathbf{A}}_i^* + \mathbf{w}_t^{\prime}\mathbf{D} + \varepsilon_t^{\prime}, \tag{2}$$

where $\mathbf{y}_t$ is an $n \times 1$ vector of endogenous variables and ε_t is an $n \times 1$ vector of structural shocks for the SOE ($\varepsilon_t \sim N(0, I_n)$ and structural shocks are independent across blocks in which $E(\varepsilon_t\varepsilon_t^{*\prime}) = \mathbf{0}_{\mathbf{n}\times\mathbf{n}^*}$). $\mathbf{A}_i$ and $\widetilde{\mathbf{A}}_i^*$ are $n \times n$ matrices of structural parameters for $i = 0, \ldots, p$ for the SOE and the big economy, respectively. Finally, $\mathbf{D}$ is an $r \times n$ matrix of structural parameters for the SOE.

The latter model can be expressed in a more compact form, so that

$$\begin{bmatrix}\mathbf{y}_t^{\prime} & \mathbf{y}_t^{*\prime}\end{bmatrix}\begin{bmatrix}\mathbf{A}_0 & \mathbf{0}\\ -\widetilde{\mathbf{A}}_0^* & \mathbf{A}_0^*\end{bmatrix} = \sum_{i=1}^{p}\begin{bmatrix}\mathbf{y}_{t-i}^{\prime} & \mathbf{y}_{t-i}^{*\prime}\end{bmatrix}\begin{bmatrix}\mathbf{A}_i & \mathbf{0}\\ \widetilde{\mathbf{A}}_i^* & \mathbf{A}_i^*\end{bmatrix} + \mathbf{w}_t^{\prime}\begin{bmatrix}\mathbf{D}\\ \mathbf{D}^*\end{bmatrix} + \begin{bmatrix}\varepsilon_t^{\prime} & \varepsilon_t^{*\prime}\end{bmatrix}\begin{bmatrix}I_n & \mathbf{0}\\ \mathbf{0} & I_{n^*}\end{bmatrix},$$

or simply

$$\overrightarrow{\mathbf{y}}_t^{\prime}\overrightarrow{\mathbf{A}}_0 = \sum_{i=1}^{p}\overrightarrow{\mathbf{y}}_{t-i}^{\prime}\overrightarrow{\mathbf{A}}_i + \mathbf{w}_t^{\prime}\overrightarrow{\mathbf{D}} + \overrightarrow{\varepsilon}_t^{\prime}, \tag{3}$$

where $\overrightarrow{\mathbf{y}}_t^{\prime} \equiv \begin{bmatrix}\mathbf{y}_t^{\prime} & \mathbf{y}_t^{*\prime}\end{bmatrix}$, $\overrightarrow{\mathbf{A}}_i \equiv \begin{bmatrix}\mathbf{A}_i & \mathbf{0}\\ \widetilde{\mathbf{A}}_i^* & \mathbf{A}_i^*\end{bmatrix}$ for $i = 1, \ldots, p$, $\overrightarrow{\mathbf{D}} \equiv \begin{bmatrix}\mathbf{D}\\ \mathbf{D}^*\end{bmatrix}$ and $\overrightarrow{\varepsilon}_t^{\prime} \equiv \begin{bmatrix}\varepsilon_t^{\prime} & \varepsilon_t^{*\prime}\end{bmatrix}$;
thus, system (2) represents an SOE in which its dynamics are influenced by the big economy block (1) through the parameters $\widetilde{\mathbf{A}}_0^*$ and $\widetilde{\mathbf{A}}_i^*$.

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

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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 SOEs such as the Latin American ones, since they are influenced by external shocks like the QE policies implemented in the US economy.

2.2. Reduced-Form Estimation

The system (3) is estimated by blocks. We first work on the big economy block, then the SOE block, and finally present a compact-form system in which these blocks are stacked into one system.

2.2.1. Big economy block. The independent SVAR (1) can be written as

$$\mathbf{y}_t^{*\prime}\mathbf{A}_0^* = \mathbf{x}_t^{*\prime}\mathbf{A}_+^* + \varepsilon_t^{*\prime},$$

where

$$\mathbf{A}_+^{*\prime} \equiv \left[\, \mathbf{A}_1^{*\prime} \cdots \mathbf{A}_p^{*\prime} \; \mathbf{D}^{*\prime} \,\right], \; \mathbf{x}_t^{*\prime} \equiv \left[\, \mathbf{y}_{t-1}^{*\prime} \cdots \mathbf{y}_{t-p}^{*\prime} \; \mathbf{w}_t^{\prime} \,\right],$$

so that its reduced-form representation is

$$\mathbf{y}_t^{*\prime} = \mathbf{x}_t^{*\prime}\mathbf{B}^* + \mathbf{u}_t^{*\prime}, \tag{4}$$

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 $E\left[\mathbf{u}_t^*\mathbf{u}_t^{*\prime}\right] = \Sigma^* = \left(\mathbf{A}_0^*\mathbf{A}_0^{*\prime}\right)^{-1}$. Then the coefficients $\mathbf{B}^*$ are estimated from (4) by ordinary least squares (OLS), so that

$$\widehat{\mathbf{B}}^* = \left[\sum_{t=1}^{T} \mathbf{y}_t^{*\prime}\mathbf{x}_t^*\right]\left[\sum_{t=1}^{T} \mathbf{x}_t^{*\prime}\mathbf{x}_t^*\right]^{-1},$$

and Σ^* is recovered through the estimated residuals $\widehat{\mathbf{u}}_t^{*\prime} = \mathbf{y}_t^{*\prime} - \mathbf{x}_t^{*\prime}\widehat{\mathbf{B}}^*$.

2.2.2. SOE block. The SVAR (2) is written as

$$\mathbf{y}_t^{\prime}\mathbf{A}_0 = \mathbf{x}_t^{\prime}\mathbf{A}_+ + \varepsilon_t^{\prime},$$

where

$$\begin{aligned} \mathbf{A}_+^{\prime} &\equiv \left[\, \mathbf{A}_1^{\prime} \cdots \mathbf{A}_p^{\prime} \; \widetilde{\mathbf{A}}_0^* \; \widetilde{\mathbf{A}}_1^* \cdots \widetilde{\mathbf{A}}_p^* \; \mathbf{D}^{\prime} \,\right] \\ \mathbf{x}_t^{\prime} &\equiv \left[\, \mathbf{y}_{t-1}^{\prime} \cdots \mathbf{y}_{t-p}^{\prime} \; \mathbf{y}_t^{*\prime} \; \mathbf{y}_{t-1}^{*\prime} \cdots \mathbf{y}_{t-p}^{*\prime} \; \mathbf{w}_t^{\prime} \,\right]; \end{aligned}$$

thus, the reduced form is

$$\mathbf{y}_t^{\prime} = \mathbf{x}_t^{\prime}\mathbf{B} + \mathbf{u}_t^{\prime}, \tag{5}$$

where $\mathbf{B} \equiv \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t^{\prime} \equiv \varepsilon_t^{\prime}\mathbf{A}_0^{-1}$, and $E\left[\mathbf{u}_t\mathbf{u}_t^{\prime}\right] = \Sigma = \left(\mathbf{A}_0\mathbf{A}_0^{\prime}\right)^{-1}$. As a result, foreign variables are treated as predetermined in this block. In this case, coefficients $\mathbf{B}$ are estimated from (5) by OLS, and Σ is recovered through the estimated residuals $\widehat{\mathbf{u}}_t^{\prime} = \mathbf{y}_t^{\prime} - \mathbf{x}_t^{\prime}\widehat{\mathbf{B}}$.

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2.2.3. Compact form. It is worth mentioning that the two reduced forms can be stacked into a single model, so that the SVAR model (3) can be estimated by usual methods. The model can be written as

$$\overrightarrow{\mathbf{y}}'_t \overrightarrow{\mathbf{A}}_0 = \overrightarrow{\mathbf{x}}'_t \overrightarrow{\mathbf{A}}_+ + \overrightarrow{\varepsilon}'_t,$$

where

$$\overrightarrow{\mathbf{A}}'_+ \equiv \left[\overrightarrow{\mathbf{A}}'_1 \cdots \overrightarrow{\mathbf{A}}'_p \ \overrightarrow{\mathbf{D}} \right]$$
$$\overrightarrow{\mathbf{x}}'_t \equiv \left[\overrightarrow{\mathbf{y}}'_{t-1} \cdots \overrightarrow{\mathbf{y}}'_{t-p} \ \mathbf{w}'_t \right].$$

The reduced form is now

$$\overrightarrow{\mathbf{y}}'_t = \overrightarrow{\mathbf{x}}'_t \overrightarrow{\mathbf{B}} + \overrightarrow{\mathbf{u}}'_t, \tag{6}$$

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 $E\left[\overrightarrow{\mathbf{u}}_t \overrightarrow{\mathbf{u}}'_t\right] = \overrightarrow{\Sigma} = \left(\overrightarrow{\mathbf{A}}_0 \overrightarrow{\mathbf{A}}'_0\right)^{-1}$. In this case, if we estimate $\overrightarrow{\mathbf{B}}$ by OLS, this must be performed by taking into account the block structure of the system imposed in matrices $\overrightarrow{\mathbf{A}}_i$, that is, 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 Akaike information criterion (AIC).

2.2.4. Priors. In line with Arias et al. (2018), we use conditionally agnostic priors over the parameterizations subject to the sign restrictions. The algorithms in Arias et al. (2018) are written over the orthogonal reduced-form parameterization and use conjugate priors. These authors argue that the likelihood function does not bear any information about the orthogonal matrices, meaning that any conjugate prior over the orthogonal reduced-form parameterization is over the set of orthogonal matrices and, as a result, it is a conditionally agnostic prior over the orthogonal reduced-form parameterization. Therefore, the conjugate posterior is a normal-inverse-Wishart over the reduced-form parameters and at over the set of orthogonal matrices. Furthermore, while the current numerical algorithms make independent draws from conditionally agnostic posteriors over the orthogonal reduced-form parameterization, they are also making independent draws from the equivalent conditionally agnostic posterior.[6]

2.3. Identification of Structural Shocks

Given the estimation of the reduced form, now we turn to the identification of structural shocks. In short, we need a matrix $\overrightarrow{\mathbf{A}}_0$ in (3) that satisfies a set of identification restrictions. To this end, here we adopt a partial identification strategy. That is, since the model size $\left(\overrightarrow{n} = \dim \overrightarrow{\mathbf{y}}_t\right)$ is potentially large, the task of writing a full structural identification procedure is far from straightforward (Zha, 1999). In turn, we stress the idea of partial identification, since in general we are only interested in some of the shocks $\underline{n} < \overrightarrow{n}$ in the SVAR model: namely, domestic and foreign monetary policy shocks. In this regard, Arias et al. (2018) propose an efficient routine for achieving identification through zero and sign restrictions. We adapt their routine for the case of block exogeneity.

The algorithm for the estimation is as follows:[7]

1. Set first $K = 2000$ number of draws.
2. Draw $(\mathbf{B}^*, \Sigma^*)$ from the posterior distribution of the big economy (foreign) block.
3. Denote $\mathbf{T}^*$ such that $\left(\mathbf{A}_0^*, \mathbf{A}_+^*\right) = \left((\mathbf{T}^*)^{-1}, \mathbf{B}^* (\mathbf{T}^*)^{-1}\right)$ and draw an orthogonal matrix $\mathbf{Q}^*$ such that $\left((\mathbf{T}^*)^{-1} \mathbf{Q}^*, \mathbf{B}^* (\mathbf{T}^*)^{-1} \mathbf{Q}^*\right)$ satisfies the zero and sign restrictions of the QE shock, and recover the draw $\left(\mathbf{A}_0^*\right)_k = (\mathbf{T}^*)^{-1} \mathbf{Q}^*$.
4. Draw $(\mathbf{B}, \Sigma)$ from the posterior distribution of the SOE (domestic) block.
5. Denote $\mathbf{T}$ such that $(\mathbf{A}_0, \mathbf{A}_+) = \left(\mathbf{T}^{-1}, \mathbf{B}\mathbf{T}^{-1}\right)$ and draw an orthogonal matrix $\mathbf{Q}$ such that $\left(\mathbf{T}^{-1}, \mathbf{B}\mathbf{T}^{-1}\right)$ satisfies the monetary rule restrictions on the SOE, and recover the draw $(\mathbf{A}_0)_k = \mathbf{T}^{-1}\mathbf{Q}$.
6. Take the draws $(\mathbf{A}_0)_k$ and $\left(\mathbf{A}_0^*\right)_k$, then recover the system (3), and compute the impulse responses.
7. If restrictions are satisfied, keep the draw, and set $k = k + 1$. If not, discard the draw and go to step 8.
8. If $k < K$, return to step 2, otherwise stop.

In this regard, it is worth to remark three aspects related with this routine:

- Draws from the posterior are independent from each other.
- Draws from the reduced form of the two blocks $(\mathbf{B}, \Sigma)$ and $(\mathbf{B}^*, \Sigma^*)$ are independent by construction.
- The procedure in Arias et al. (2019) normalizes the size of the shock in order to be one standard deviation.

2.4. Monetary Policy Rule in an SOE

All the Latin American economies we analyze here follow inflation targeting as a monetary policy. This scheme has a systematic component for the policymaker to react to economic conditions, usually associated with inflation and output. As in Arias et al. (2019), without considering the effects of the big economy for simplicity, let the first shock be the monetary policy shock. Thus, the first equation of the SOE (domestic) block,

$$\mathbf{y}_t'\mathbf{a}_{0,1} = \sum_{i=1}^{p} \mathbf{y}_{t-i}'\mathbf{a}_{i,1} + \varepsilon_{1t}, \tag{7}$$

is the monetary policy equation, where ε_{1t} denotes the first entry of ε_t, $a_{i,1}$ denotes the first column of A_i for $0 \le i \le p$, and $a_{i,jk}$ denotes the (j, k) entry of A_i. The latter describes the systematic component of monetary policy. Thus, in order to restrict the systematic component of the monetary policy, we need to restrict $a_{i,1}$.

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In line with Arias et al. (2019), we impose a monetary policy rule on the SOE; that is, the interest rate is the monetary policy instrument and the contemporaneous reaction of the interest rate to output and prices is usually positive. In addition, the parameter of the interest rate is set as positive in order to satisfy the regularity conditions highlighted in Arias et al. (2018). The contemporaneous timing assumption warrants some justification. As argued by Arias et al. (2019), when central banks decide how to set the policy rate, they do not have data on output and prices available for the current month. However, forward-looking central banks have access to real-time indicators in order to learn about the current state of economic activity and prices.

To implement this identification strategy, the reduced-form VAR consists of six endogenous variables that are ordered as follows: output, y_t; price, p_t; exchange rate, e_t; bank lending credit in domestic currency, cd_t; bank lending credit in foreign currency, cf_t; and a policy interest rate, i_t. Thus, equation (7), abstracting from lag variables, can be written as

$$i_t = \psi_y y_t + \psi_p p_t + \psi_e e_t + \psi_{cd} cd_t + \psi_{cf} cf_t + \sigma \varepsilon_{1t}; \qquad (8)$$

restrictions on the systemic component of the monetary policy rule imply $\psi_{cd} = \psi_{cf} = 0$ and $\psi_y, \psi_p > 0$, and ψ_e remains unrestricted. The impulse response functions to a contractionary domestic monetary policy shock in an SOE (Latin American economies) that satisfies the monetary rule restrictions are shown in Appendix B.[8]

3. RESTRICTIONS FOR IDENTIFYING A QE POLICY SHOCK

In this section, we assess the transmission mechanism of a structural QE policy shock. First, we consider the USA as the big economy, and Chile, Colombia, Mexico, or Peru as the SOEs. For the USA, we include the following variables: (i) an economic policy uncertainty index (uncertainty); (ii) an indicator related to the spread between long- and short-term interest rates (spread); (iii) M1 aggregate money (money supply); (iv) the federal funds rate (FFR) (interest rate); (v) the consumer price index (price); and (vi) the industrial production index (output). As to the SOEs, we consider: (i) exchange rate; (ii) the interbank interest rate in domestic currency (interest rate); (iii) credit in foreign currency; (iv) credit in domestic currency; (v) the consumer price index (price); and (vi) an indicator of economic activity (output).[9]

With regard to policy uncertainty, Bloom (2009) builds a model based on firm-level data to simulate a macro uncertainty shock. In this scenario, the uncertainty shock brings about a rapid drop and rebound in aggregate output and employment because higher uncertainty leads to a slowdown in investment and hiring. In the medium term, the increased volatility from the shock induces an overshoot in output and employment, and generates short sharp recessions and recoveries.[10]

TABLE 1. Identification restrictions for a QE policy shock in the USA

Variable	QE shock ($h = 0$)	QE shock ($h = 1, 2$)
Uncertainty	?	?
Spread	−	−
Money supply	+	+
Interest rate	0	0
Price	0	?
Output	0	?

Note: ? = left unconstrained.

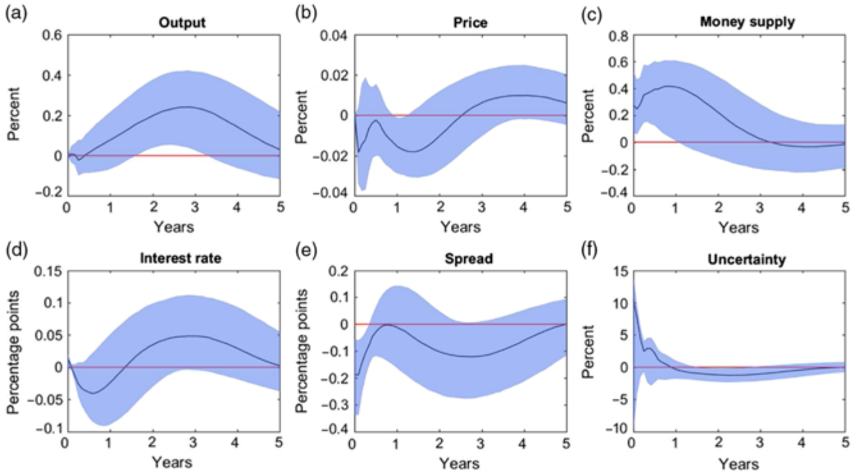
We identify the QE shock that imposes minimal restrictions in the US economy block. In short, we identify a QE shock that increases the level of US money aggregates and, at the same time, decreases the level of spreads in the yield curve spreads, while the FFR goes unchanged because of the ZLB (see Table 1). In addition, since price level and economic activity are non-policy variables, we assume that they only react to the policy shock after one period (i.e., they are considered to be slow variables).

Similar identification strategies for unconventional monetary policy shocks through sign and zero restrictions can be found in Peersman (2011), Gambacorta et al. (2014), Baumeister and Benati (2013), and Schenkelberg and Watzka (2013). In line with this literature, the QE policy shock is identified using a mixture of zero and sign restrictions; moreover, we impose that those sign restrictions must be satisfied for a 3-month horizon. One aspect worth mentioning is the flexibility of our identification scheme; since we do not know the true model that contains the shock, we capture the parameters region that satisfies our restrictions, which might include several different structural models; moreover, our QE policy shock is such that the monetary policy instrument may be either the aggregate money or the term spread; thus for this reason, we do not normalize the shock to one particular variable.

4. RESULTS

4.1. The US Economy

The results for the US economy are shown in Figure 3. A QE policy shock increases the money stock, reduces the spread between the long- and short-term interest rates, and keeps the FFR close to zero. Strictly speaking, this is an unconventional expansionary policy shock and, as a result, it has a positive and significant effect on industrial production in the medium term.[11] Our results are significant in the short and medium run, which is in line with Peersman (2011), Gambacorta et al. (2014), Baumeister and Benati (2013), and Schenkelberg and Watzka (2013). Moreover, it can also be observed that the effect on spreads is not persistent and vanishes rapidly, in line with Wright (2012).



Note: Median value (solid line) and 68% bands (shadow area).

FIGURE 3. Response of US variables after a QE policy shock.

First of all, an unconventional monetary policy aims at stimulating economic activity and avoiding a severe depression. In our scenario, the short-term interest rate reaches its ZLB and then becomes ineffective. In the real world, a central bank has close control over narrow reserve aggregates—such as the monetary base or a short-term interest rate—because of the lack of direct control over money supply, inflation, or long-term interest rates [see Walsh (2010)]. A central bank that implements a QE policy buys a certain quantity of financial assets from financial institutions, thus increasing the monetary base and lowering the yield of those assets. Furthermore, monetary authorities may use QE to stimulate the economy by purchasing assets of longer maturity, thereby lowering longer-term interest rates further out on the yield curve [see Jones and Kulish (2013)].

Then, QE policy measures increase private-sector liquidity, mainly through the purchase of long-term securities. That is, the QE episode is characterized by a sharp increase in the size of the Fed balance sheet, together with an increase in money aggregates (e.g., M1), a decrease in the long versus short interest rate spread, and a short-term interest rate unchanged and very close to zero.[12]

According to Baumeister and Benati (2013), unconventional policy interventions in the treasury market also narrowed the spread between long- and short-term government bonds. The latter triggered an increase in economic activity and a decline in inflation by removing duration risk from portfolios and by reducing the borrowing costs for the private sector. Moreover, according to Bernanke (2006), if the aggregate demand depends on long-term interest rates, then special factors that lower the spread between short- and long-term rates will stimulate the economy. Bernanke (2006) states that a higher short-term rate is required to obtain consistent financial conditions with maximum sustainable employment and stable prices if the term premium declines.[13]

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4.2. Latin American Economies

According to our empirical strategy, the identified QE policy shock from the USA hits the SOEs as in (2). In this step, we consider how this shock affects four Latin American countries: Chile, Colombia, Mexico, and Peru. In general, central banks in developing countries took into account most of the effects from QE policies and adopted macroprudential policies to deal with a new environment in which there are two policy stability objectives—macroeconomic and financial—because of the sudden change in the link between the macroeconomy and the financial markets. Secondly, following the Tinbergen principle, a policymaker requires two instruments for two policy objectives. For most Latin American countries within an inflation-targeting framework that principle implies a policy short-term interest rate and a macroprudential tool.[14]

As we have seen, macroprudential policies implemented by the central banks in our sample were intended to curb exchange rate volatility, capital flows (to prevent an excessive increase in credit markets), and asset prices. These policies have been adopted at differing speeds and times, with different preferences in terms of frequency of intervention and willingness to affect financial markets. In Peru, policies associated with managing reserve requirements and exchange rate volatility have been key to stabilizing the financial sector. On the other hand, the financial sector in Chile and Mexico avoided excessive impact since most activity in previous years was associated with implementation of Basel III regulatory policies.

Taking each case country by country, Figure 4 presents our results for Chile. We find an exchange rate appreciation, an increase in credit in foreign currency, and an increase in output as a consequence of massive capital inflows. Although other emerging economies reacted by implementing macroprudential policies, the Central Bank of Chile did not implement explicit policies of this kind. In this regard, Raddatz and Vergara (2016) argue that because of good macroeconomic management and adequate regulation and supervision, the Central Bank of Chile has not perceived an over-expansion of bank lending credit, and thus has not deemed it necessary to engage in this type of policies.

Figure 5 shows our results for Colombia. We find no evidence of effects from a US QE shock. A possible explanation for this is that this country has been very active in implementing macroprudential policies in order to contain excessive credit growth, in the context of large capital inflows. In Colombia, the use of reserve requirements on domestic deposits was complemented with capital controls such as reserve requirements on foreign indebtedness, portfolio inflows, and limits on the net foreign exchange position; the Central Bank of Colombia also considered tighter macroprudential measures, such as the introduction of limits on the banks' positions on derivative products (Tovar et al., 2012; Carrera, 2013).

In regard to Peru, Figure 6 shows an exchange rate appreciation but no effect on other macroeconomic variables. Similar to Colombia, Peru has been very active

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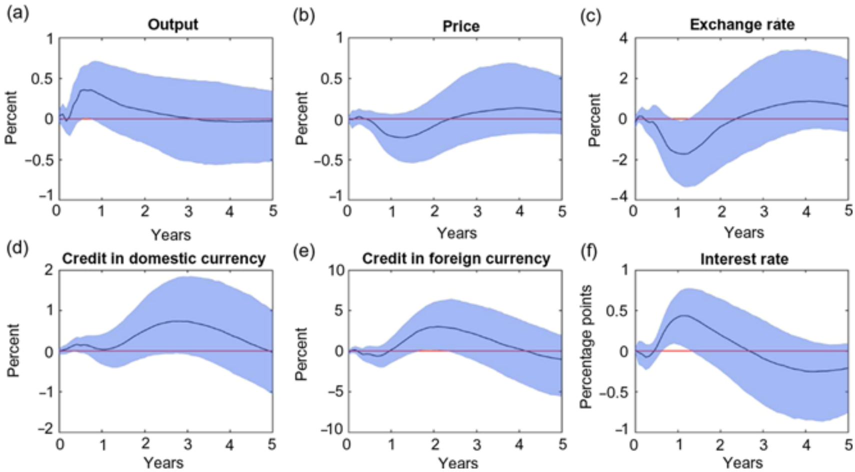
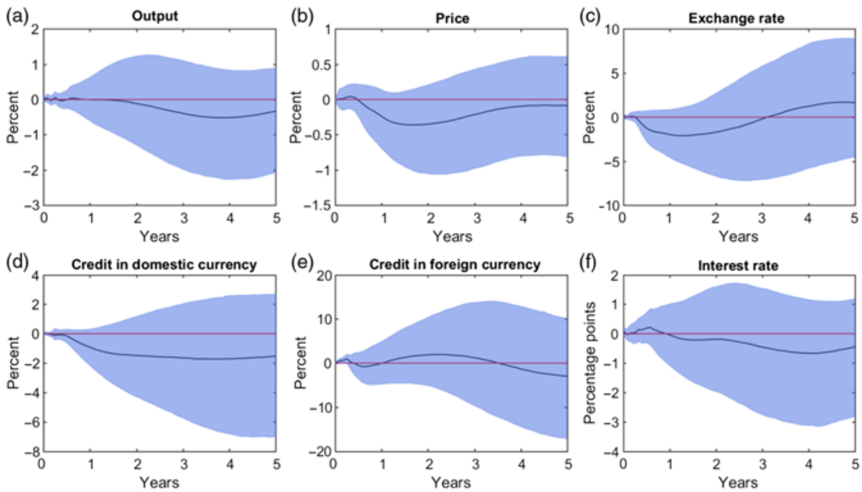


Note: Median value (solid line) and 68% bands (shadow area).

FIGURE 4. Response of Chilean variables after a QE policy shock.



Note: Median value (solid line) and 68% bands (shadow area).

FIGURE 5. Response of Colombian variables after a QE policy shock.

in implementing macroprudential policies; in addition to a short-term policy rate, the Central Bank of Peru also implements different forms of reserve requirements (in domestic and foreign currencies) as well as liquidity sterilization and foreign exchange rate interventions (since Peru is an economy characterized by partial dollarization of the banking system).[15]

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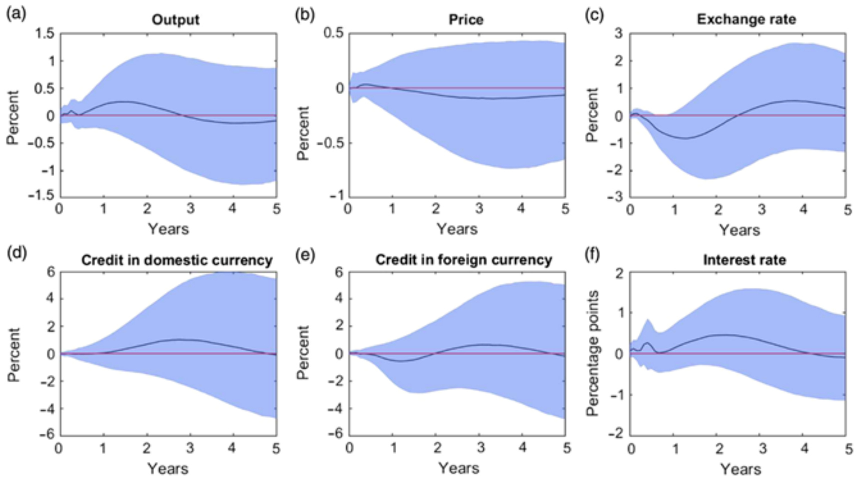
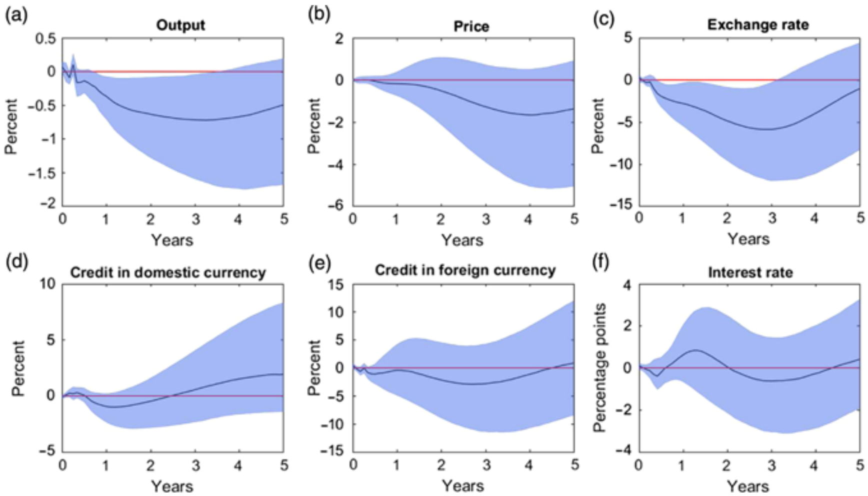


Note: Median value (solid line) and 68% bands (shadow area).

FIGURE 6. Response of Peruvian variables after a QE policy shock.



Note: Median value (solid line) and 68% bands (shadow area).

FIGURE 7. Response of Mexican variables after a QE policy shock.

In the case of Mexico, Figure 7 shows an exchange rate appreciation, a negative effect on output, and no effect on other macroeconomic variables. Similarly to Chile, Mexico did not respond actively with new macroprudential policies. The effects on output seem to be led by the limits of the exchange rate on output. Here, macroprudential policies were introduced following the financial crisis of

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1995 and updated after the 2007–2008 global financial crisis. Thus, as it is argued by Ruiz et al. (2014), the impact of excessive overall liquidity on domestic assets and credit markets is not significant, as capital inflows have not been channeled through the banking system.

As we initially hypothesized, the QE shock has had a differentiated effect on each country; however, there are common trends in the response of macroeconomic variable responses.[16] In general, our results point to an appreciation, significant in Chile, Peru, and Mexico, which is in line with the massive influx of capital into the region. Countries such as Peru have been seen to react the most in the face of this type of shock, which is consistent with a more active exchange rate policy in the Forex market.

The US QE shock produces a credit expansion in both foreign and domestic currencies, which in turn triggers a positive response in the domestic interest rate in the medium term; nonetheless, most of the effects are not significant, except for Chile. Here we notice that the credit expansion is stronger in the foreign currency than in the domestic one, which suggests that credit conditions became more attractive for domestic firms. This portfolio effect seems to be stronger in Chile. The reaction of financial variables, such as credit in Chile, is stronger than the reaction of output and prices, following the shock. Similarly, in all four of the Latin American countries analyzed, the QE shock has little effect on inflation in the short term; if anything, the result would be a decrease in prices, probably associated with the exchange rate pass-through, which tends to appreciate because of the capital inflows.

In regard to output, this effect of the QE shock is significant in Mexico and Chile; in Chile it is positive due to the recovery of the US economy; while in Mexico (an economy that is closer to the USA) it is negative, which may be due to the greater exchange rate appreciation in that country dominating the positive effects of the US economy's recovery, that is, exported products become relatively more expensive and the country thus becomes much less competitive in international markets. Indeed, almost 80% of Mexico's total exports go to the US market, and a considerable proportion of those exports are durable goods (Sidaoui et al., 2010); moreover, the USA spending on durable goods was moderate during the current recovery (Van Zandweghe and Braxton, 2013). In addition, Ibarra (2011) finds strong empirical evidence to show that appreciation has had a negative effect on private investment in Mexico, by squeezing profit margins in the capital-intensive tradable sectors.

There is significant heterogeneity among the four Latin American countries in terms of adopting macroprudential policies, since the impact of global turbulences varies significantly across them. While Colombia and Peru have been very active in implementing several macroprudential measures, Chile has not explicitly implemented such policies and Mexico started adopting macroprudential policies after the 1995 financial crisis. For these reasons, the effectiveness of a particular macroprudential policy requires a country-by-country analysis that is beyond the scope of our study.[17]

5. CONCLUDING REMARKS

We identified a structural QE policy shock in a standard SVAR model. We quantified the effects arising from this shock (which has its origins in the US economy) on four Latin American countries: Colombia, Chile, Mexico, and Peru. As to the transmission mechanism, we highlighted the importance of financial markets.

With reference to these SOEs, our results suggest the effects of a QE policy shock on financial variables are greater than those on output and prices. The increase in international liquidity that follows each round of QE appears to be transmitted to the macroeconomic variables of the SOEs through financial variables such as interest rates, aggregate bank lending credit, and exchange rates.

As mentioned in the early literature, most central banks in developing countries anticipated these effects and adopted macroprudential policy measures. In general, these policies give rise to credit growth (via reserve requirements) and exchange rate volatility (via foreign exchange interventions) and tend to mitigate the effects of a QE policy event.

Our research agenda also extended to the inclusion in the SVAR model of variables to measure macroprudential policies. Even though we argue that these effects are already captured by the variables intended as targets of such macroprudential policies, we can reinforce our results by excluding all financial variables and plugging in the variables that capture these policies.

The evaluation of QE policy effects on the lending channel is also part of our research agenda. According to Carrera (2011), there was an initial deceleration in the lending process after 2007 as a result of a flight-to-quality process. Later on, credit growth expanded at a previous growth rate given the context of capital inflows into the region. Finally, the bank lending channel identified may play a role in understanding the external shock transmission mechanism, taking into account their effects on the credit loan market.

NOTES

1. Unconventional monetary policy measures include QE policy, credit easing, and signaling. In the case of credit easing, a central bank purchases private-sector assets in order to improve liquidity and credit access. Signaling policy refers to central bank communication, that is, the use of statements with the purpose of lowering market expectations of future interest rates.

2. The discussion at this stage revolves around targeting a single goal. The main concern is the overall effect that each instrument has, because each is likely to affect more than one objective.

3. See Eichengreen (2013) who summarizes the efforts made by central banks to reduce distortions in the financial sector caused by excessive exchange rate volatility. See Cronin (2014) and Forbes et al. (2016), who review the interaction between money and asset markets, which has different outcomes for emerging economies.

4. See Carrera (2013) for a review of the evolving role of reserve requirements from a prudential to a macroprudential tool, with special emphasis on Colombia and Peru; see Carrera and Vega (2012) for the complementary use of reserve requirements and interest rate; and see the "Macroprudential policy" BIS papers, which summarize the joint CBRT/BIS/IMF conference on "Macroprudential policy: effectiveness and implementation challenges" held in Turkey, 2015, and provide very specific details of different macroprudential tools in developing countries.

5. See Anaya et al. (2017) for a global VAR to assess the responses in emerging markets to a QE shock, based on key variables.

6. See Arias et al. (2019) for a discussion on priors for SVARs.

7. For more details, see Arias et al. (2018).

8. For example, in a bivariate model, let $a_{i,1}$ be the first column of A_i then $a_{i,11}$ and $a_{i,21}$ are first and second entries of $a_{i,1}$, respectively. In our case, the parameters for restricting the behavior of the interest rate are $\psi_y = -a_{0,61}^{-1} a_{0,11}$, $\psi_p = -a_{0,61}^{-1} a_{0,21}$, $\psi_e = -a_{0,61}^{-1} a_{0,31}$, $\psi_{cd} = -a_{0,61}^{-1} a_{0,41}$, $\psi_{cf} = -a_{0,61}^{-1} a_{0,51}$, and $\sigma = -a_{0,61}^{-1}$.

9. Even though capital flows are important for our analysis, this variable is not available in a monthly frequency (only quarterly, which significantly reduces the sample size). On the other hand, we already take into account their effects by including credit in both domestic and foreign currencies. Moreover, we argue that the exchange rate and interest rate behaviors provide enough information about international credit conditions. See also Appendix A for details regarding data transformation, sources, etc.

10. Bloom (2009) uses stock market volatility as a measure of uncertainty. In addition to this measure, Aastveit et al. (2017) use the JLN and the EPU index to measure the uncertainty impact on macro variables. Fontaine et al. (2017) use the policy uncertainty index from Media Tenor to assess the impact of foreign policy uncertainty over domestic macro variables.

11. This result corresponds to the sample period 1996–2016. Results are robust to different sample periods. Impulse responses depict similar results even if we consider 1996–2014, 1996–2016, or 2002–2016 as the sample periods. Given the fact that this method requires a high number of observations, the algorithm tends to fail whenever we consider a sample that begins in 2008.

12. The central bank reduces the yields of long-term assets through the Large Scaled Asset Purchase (LSAP) program. As a result, the spread between long- and short-term rates decreases, since the short-term interest rate remains unchanged.

13. Rudebusch et al. (2007) provide empirical evidence for a negative relationship between the term premium and economic activity. The authors show that a decline in the term premium of 10-year treasury yields tends to boost GDP growth.

14. At this stage, the discussion centers on targeting a single goal. The main issue is the overall effect that each instrument has because each one is likely to affect more than one objective.

15. For example, during the second part of 2010, the Central Bank of Peru took measures such as raising the reserve requirement in domestic currency, in foreign currency, and for external short-term liabilities of the financial system; moreover, the central bank set back a reserve requirement ratio for domestic currency deposits of non-resident investors (Carrera and Vega, 2012); those policies aim to isolate the Peruvian economy from the effects of the US QE policies by offsetting their outcomes.

16. We did not include Brazil in our sample because we want to identify the rebalance in the credit market, so we need credit in both domestic and foreign currencies. Even though not all results are statistically significant, we point out that the direction in the responses to the QE shock provides interesting feedback to this unusual type of shock.

17. It is difficult to capture in a single variable all of the different macroprudential measures used by each Latin American country. For example, the nominal interest rate at a given maturity can be used as a macroprudential policy; nonetheless, there are not enough observations of this series. Also, the distinction between policies and measures is important. For example, measures associated with reserve requirement policies range from the amount of money that commercial banks must hold in cash or in deposit with the central bank to the time that foreign capital has to remain in a country (see Carrera, 2013).

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APPENDIX A: DATA

We include raw monthly data for the period January 1996–December 2016, except Colombia, which spans until June 2014. In addition, most of the seasonally adjusted series are available, nonetheless series that are not available were seasonally adjusted by TRAMO/SEATS. All variables except interest rates and the spread indicator are included as logs multiplied by 100. This transformation is the most suitable one, since impulse responses can now be directly interpreted as percentage changes.

Tables B1 and B2 show the definitions of the variables used in the estimation analysis. All US variables were taken from the Federal Reserve Bank of Saint Louis website (FRED database), except interest rates, which were taken from the H.15 Statistical Release of the Board of Governors of the Federal Reserve System website. Latin American variables were taken from their respective countries' central bank website.

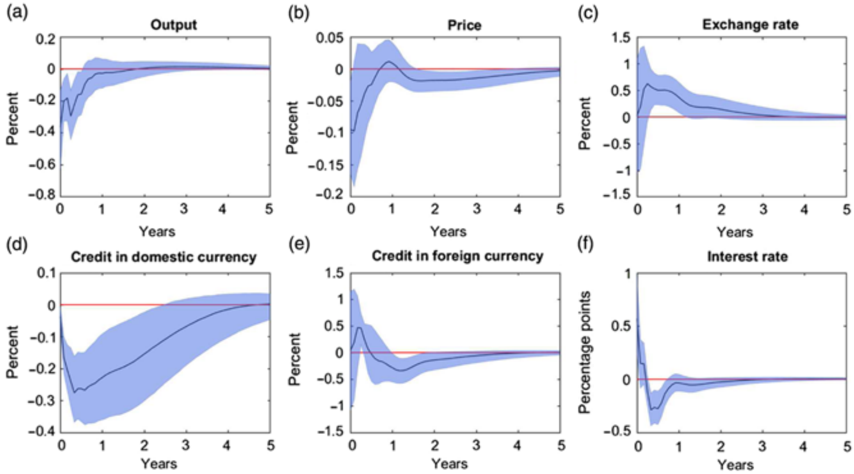
In the estimation analysis we also include exogenous variables: the producer price index (all commodities); the crude oil prices (West Texas Intermediate (WTI)—Cushing, Oklahoma); a constant term; a linear time trend (t); and a quadratic time trend (t^2). Data of exogenous prices were taken from the FRED database.

APPENDIX B: IMPULSE RESPONSES OF A DOMESTIC MONETARY POLICY SHOCK IN LATIN AMERICA

TABLE B1. US variables

Variable	Definition
Output	Industrial production index (2007 = 100), seasonally adjusted.
Price	Consumer price index for all urban consumers: all items (1982–1984 = 100), not seasonally adjusted.
Money supply	M1 money stock, not seasonally adjusted.
Interest rate	FFR.
Spread	First principal component from all the spreads with respect to the FFR: 3M, 6M, 1Y, 2Y, 3Y, 5Y, 10Y, 30Y from the treasury. In addition, we include AAA, BAA, State Bonds, and Mortgages.
Uncertainty	Economic policy uncertainty index from the USA.

Notes: The relevance of common forces driving the various spreads in the US economy implies that there is a single latent factor underlying spreads across different terms, defaults, and liquidity. Therefore, we consider this component as a spread indicator. Alternatively, the selection of a specific term as a spread indicator should not change significantly the results, since all spreads at different maturities generally move together.



Note: Median value (solid line) and 68% bands (shadow area).

FIGURE B1. Response of Chilean variables of a domestic monetary policy shock.

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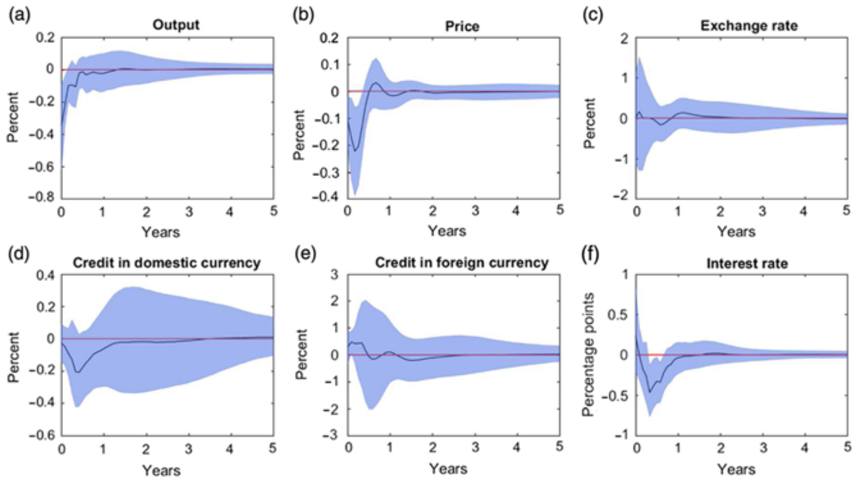
TABLE B2. Latin American variables

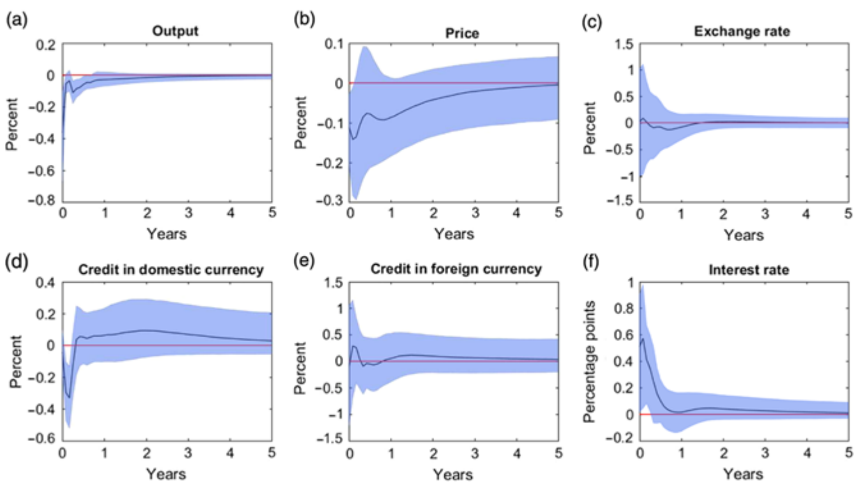
	Description			
Variable	Chile	Colombia	Mexico	Peru
Output	IMACEC monthly indicator of economic activity (2008 = 100), not seasonally adjusted.	Real industrial production index (1990 = 100), not seasonally adjusted.	IGAE global economic activity index (2008 = 100), not seasonally adjusted.	Real gross domestic product index (2007 = 100), not seasonally adjusted.
Price	Consumer price index (2008 = 100).	Consumer price index (December 2008 = 100).	Consumer price index (December 2010 = 100).	Consumer price index for Lima (2009 = 100).
Exchange rate	Chilean peso per US dollar.	Colombian peso per US dollar.	Mexican peso per US dollar.	Sol per US dollar.
Credit in domestic currency	Aggregated credit of the banking system in Chilean pesos.	Aggregated credit of the banking system in Colombian pesos.	Aggregated credit of the banking system (commercial banks) in Mexican pesos.	Aggregated credit of the banking system in Soles.
Credit in foreign currency	Aggregated credit of the banking system in US dollars.	Aggregated credit of the banking system in US dollars.	Aggregated credit of the banking system (commercial banks) in US dollars expressed in Mexican pesos.	Aggregated credit of the banking system in US dollars.
Interest rate	Interbank interest rate in Chilean pesos.	Interbank interest rate in Colombian pesos.	Interbank interest rate (at 28 days) in Mexican pesos.	Interbank interest rate in Soles.

Notes: IMACEC = Indicador Mensual de Actividad Economica, IGAE = Indicador Global de la Actividad Economica



Note: Median value (solid line) and 68% bands (shadow area).

FIGURE B2. Response of Colombian variables of a domestic monetary policy shock.



Note: Median value (solid line) and 68% bands (shadow area).

FIGURE B3. Response of Mexican variables of a domestic monetary policy shock.

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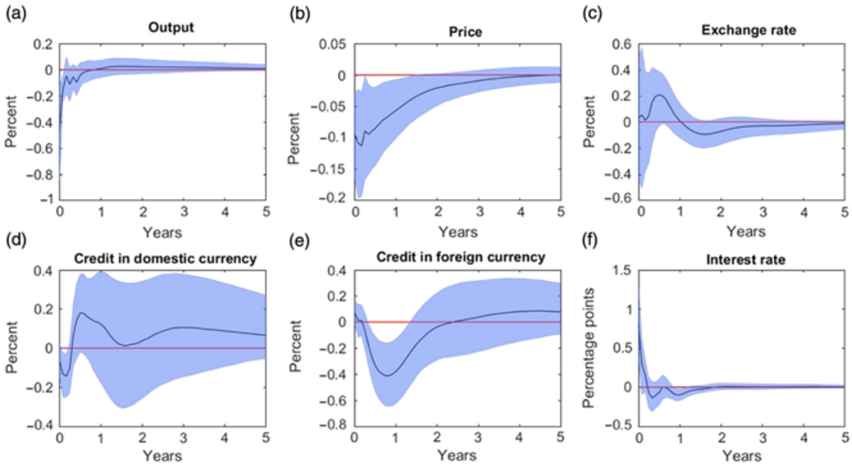

Note: Median value (solid line) and 68% bands (shadow area).

FIGURE B4. Response of Peruvian variables of a domestic monetary policy shock.

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