Effects of the U.S. Quantitative Easing over a Small Open Economy

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Abstract

Small open economies experienced different macroeconomic effects after the Quantitative Easing (QE) measures implemented by the FED. This paper quantifies those effects in terms of key macroeconomic variables for a small open economy (SOE). We first identify those QE effects as a monetary policy shock coming from a SVAR with block exogeneity and partial identification for the U.S. and the SOE (*a la* Zha, 1999). Then, following Pesaran and Smith (2012), we contrast two escenarios for the SOE of QE and no QE implementation. While we find significant effects of QE over financial variables such as credit and exchange rate, we find small but significant effects over inflation and output only in the medium term.

JEL Classification: E43, E51, E52, E58
Keywords: Zero lower bound, Quantitative easing, Structural vector autoregression, Counter-factual analysis.

1 Introduction

There has been widespread concern among policy-makers in emerging economies about the effects of Quantitative Easing (QE) policies in developed economies because these measures have triggered large surges in capital inflows to emerging countries, leading to exchange rate appreciation, high credit growth, and asset price booms. It is unclear however if those effects translate into growth and inflation in developing countries because most central banks in these countries have adopted macroprudential policies that

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mitigate any potential systemic risk in their economies.

Unconventional monetary policies have been used by central banks in developed economies to stimulate their economies because standard monetary policies have become ineffective (when the short-term interest rate is at its zero lower-bound). Walsh (2010) highlights that central banks do not directly control the nominal money supply, inflation, or long-term interest rates (likely to be most relevant for aggregate spending), however they can exercise close control over narrow reserve aggregates such as the monetary base or a short-term interest rate. Those operating procedures (relationship between central bank instruments and operating targets) were very important in what is denominated QE.

A central bank that implements QE buys a specific amount of financial assets from financial institutions, thus increasing the monetary base and lowering the yield on those assets. QE may be used by monetary authorities to further stimulate the economy by purchasing assets of longer maturity and thereby lowering longer-term interest rates further out on the yield curve (see Jones and Kulish, 2013).

In the case of the U.S., QE policies increased the private-sector liquidity, mainly through the purchase of long-term securities. The sharp increase in the balance sheet of the FED, the also sharp increase in M1, the decrease in the spread of interest rates between long- and short- term, and a short-term interes rate close to zero characterize this QE episode in the U.S. Figure (1) shows the policy rate close to zero, and how the spread between long- and short- term interest rate decreases at the beginning of November 2008.[1] Figure (2) presents the composition of the FED's balance sheet and it is clear the sharp increase in securities, especially of long-term Treasury bonds and Mortgage-Backed Security (MBS) at the early November 2008

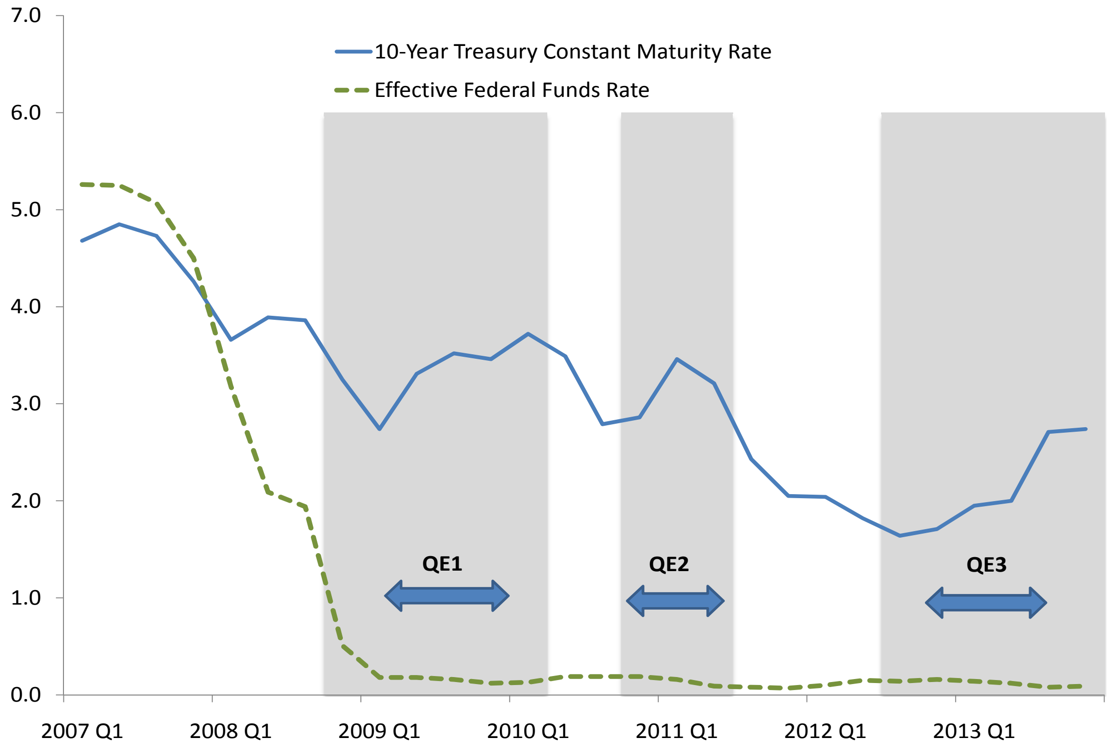
According to Baumeister and Benati (2012) the unconventional policy interventions in the Treasury market narrow the spread between long- and short-term government bonds and that trigger the economic activity and the decline in inflation by removing duration risk from portfolios and by reducing the borrowing costs for the private sector. According to Bernanke (2006) if spending depends on long-term interest rates, special factors that lower the spread between short- and long-term rates will stimulate aggregate demand. Even more, Bernanke (2006) argues that, when the term premium declines, a higher short-term rate is required to obtain the long-term rate and the overall mix of financial conditions consistent with maximum sustainable employment and stable prices.[2]

Central banks in the U.S., the U.K., Canada, Japan, and the Euro area pushed their policy rates close to their lower bound of zero. At the same time, they implemented alternative policy instruments and adopted macroprudential measures orientated to close monitoring and supervision of financial institutions. Financial stability became one of the

[1] The buying of long-term financial assets lower their yields, so the spread tends to decrease, starting from the beginning of QE.

[2] Rudebusch et al. (2007) provides empirical evidence for a negative relationship between the term premium and economic activity. The authors show that a decline in the term premium of ten-year Treasury yields tends to boost GDP growth.

Figure 1. ***Long- and Short-term interest rates***



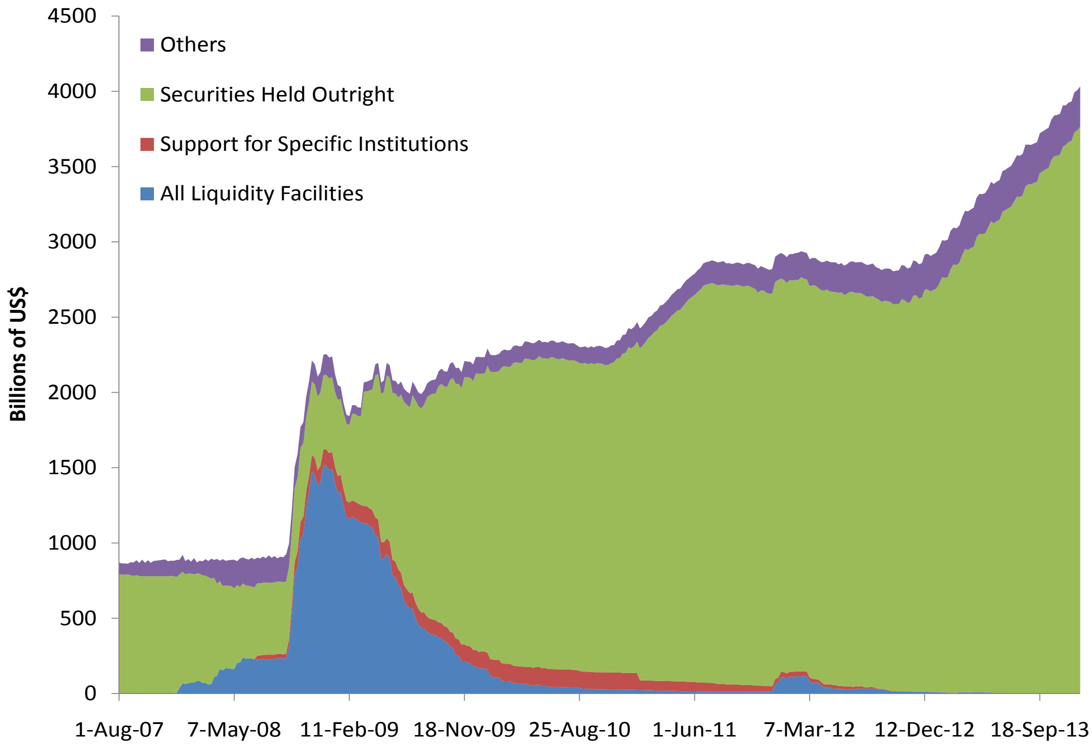
Source: Federal Reserve Economic Data (FRED).

main policy targets. The expansion of the central bank's balance sheet through purchases of financial securities and announcements about future policy (influencing expectations) were usual instruments.[3]

Jones and Kulish (2013), Hamilton and Wu (2012), Gagnon et al. (2011), and Taylor (2011) analyse the effects of QE on the global economy, but most of them focus on the behavior of financial variables, such as long-term interest rate spreads. There is some work that analyses the effects on other macroeconomic variables, but focus on the behavior of some key macroeconomic variables within the same economy: Glick and Leduc (2012) for the case of the U.S.; Lenza et al. (2010) and Peersman (2011) for the Euro Area; and, Schenkelberg and Watzka (2013) for Japan. Gambacorta et al. (2012) does a similar analysis for eight developed countries. Belke and Klose (2013) and Fratzscher et al. (2013) study the spillover effects between the U.S. and the Euro area. Baumeister and Benati (2012) works on the QE effects in the U.S. and the U.K. Curdia and Woodford

[3] Unconventional monetary policy are other forms of monetary policy that are used when interest rates are at or near the zero-lower-bound and there are concerns about deflation. These include QE, credit easing, and signaling. In credit easing, a central bank purchases private sector assets, in order to improve liquidity and improve access to credit. Signaling refers to the use of actions that lower market expectations for future interest rates. For example, during the credit crisis of 2008, the U.S. FED indicated rates would be low for an "extended period," and the Bank of Canada made a "conditional commitment" to keep rates at the lower bound of 25 basis points until the end of the second quarter of 2010.

Figure 2. ***FED's balance sheet***



Source: Federal Reserve Economic Data (FRED).

(2011) works on a theoretical approach to the central bank balance sheet.

On the other hand, central banks from developing countries anticipated most negative effects from QE policies and adopted their own macroprudential policies. Here the variables of interest are mostly financial. The focus of those policies were over variables such as exchange rate, capital flows, credit markets, and asset prices.[4]

In this regard, a brand of the literature has analysed the effectiveness of unconventional monetary policy measures taken by central banks in both advanced and emerging economies. Policy-makers are interested in estimating the QE impact on output and inflation. However, most work is focused on developed countries and little work has been done to consider spillover effects of these policy measures to emerging market countries.

Our work focuses on the macroeconomic effects of QE measures implemented by the FED over Peru, a small open economy (SOE). We estimate a SVAR with block exogeneity and partial identification in line with Zha (1999). Our main goal is to identify one QE monetary policy shock that comes from the system that represents the U.S. (a QE shock). In order to do so, we impose sign restrictions that characterize a QE event. This shock,

[4] The effects over exchange rate are discussed in Eichengreen (2013). See Cronin (2013) for the interaction between money and asset markets, and its effect on emerging economies. The case of Peru is documented in Quispe and Rossini (2011).

then, is transmitted to the block that models the Peruvian economy. The advantage of block exogeneity is how the transmission of the shock works: we model this system in such a way that the QE shock in the U.S. has effects on Peru and any shock from Peru has no effects on the U.S.

The second part of our empirical strategy is to contrast two escenarios: (i) with QE policies, and (ii) without QE policies. We use our SVAR results and perform an ex-ante policy exercise in line with Pesaran and Smith (2012). Conditional on the evolution of key variables, we evaluate the impact of QE measures over inflation and output in Peru.

The remaining of the paper is divided as follows: Section 2 introduces the SVAR model with block exogeneity, Section 3 shows the counterfactual analysis, and Section 4 concludes.

2 A SVAR model with block exogeneity

In terms of the methodology, previous work that studies other types of credit easing policies using VAR methodologies includes Schenkelberg and Watzka (2013), where they use a structural VAR to analyse the real effects of quantitative easing measures in the Japanese economy using zero and sign restrictions. They find that a QE-shock leads to a 7 percent drop in long-term interest rates and a 0.4 percent increase in industrial production. The work of Baumeister and Benati (2012) uses a SVAR with sign restrictions for QE effects in the U.S. and the U.K., argues that sign restrictions are fully compatible with general equilibrium models, and find that compressions in the long-term yield spread exert a powerful effect on both output growth and inflation.

Cushman and Zha (1997) argues that the imposition of block exogeneity in a SVAR is a natural extension for small open economy models because it helps the identification of the monetary reaction function from the viewpoint of the small open economy. The use of block exogeneity also reduces the number of parameters needed to estimate the small open economy block.

2.1 The setup

Consider a two-block SVAR model. We take this specification in order to be in line with a small open economy setup. In this context, the big economy is represented by

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

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 defined 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

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

or simply

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

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

System (2) represents the small open economy in which its dynamics are 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. 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). 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 unconventional monetary policies in the U.S. economy.

2.2 Reduced form estimation

The system (3) is estimated by blocks. 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

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

where

$$\mathbf{A}_+^{*\prime} \equiv \begin{bmatrix} \mathbf{A}_1^{*\prime} & \cdots & \mathbf{A}_p^{*\prime} & \mathbf{D}^{*\prime} \end{bmatrix}, \ \mathbf{x}_t^{*\prime} \equiv \begin{bmatrix} \mathbf{y}_{t-1}^{*\prime} & \cdots & \mathbf{y}_{t-p}^{*\prime} & \mathbf{w}_t^{\prime} \end{bmatrix}$$

so that its reduced form representation is

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

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

2.2.2 Small open economy block

The SVAR (2) is written as

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

where

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

The reduced form is now

$$\mathbf{y}_t^{\prime} = \mathbf{x}_t^{\prime}\mathbf{B} + \mathbf{u}_t^{\prime} \text{ for } t = 1, \ldots, T \tag{5}$$

where $\mathbf{B} \equiv \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t^{\prime} \equiv \varepsilon_t^{\prime}\mathbf{A}_0^{-1}$, and $E\left[\mathbf{u}_t\mathbf{u}_t^{\prime}\right] = \mathbf{\Sigma} = \left(\mathbf{A}_0\mathbf{A}_0^{\prime}\right)^{-1}$. As we can see, foreign variables are treated as predetermined in this block, i.e. it can be considered as a VARX model (Ocampo and Rodríguez, 2011). In this case, coefficients $\mathbf{B}$ are estimated from (5) by OLS, and $\mathbf{\Sigma}$ is recovered through the estimated residuals $\widehat{\mathbf{u}}_t = \mathbf{y}_t^{\prime} - \mathbf{x}_t^{\prime}\widehat{\mathbf{B}}$.

2.2.3 Compact form

It is worth to mention 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

$$\overrightarrow{\mathbf{y}}_t^{\prime}\overrightarrow{\mathbf{A}}_0 = \overrightarrow{\mathbf{x}}_t^{\prime}\overrightarrow{\mathbf{A}}_+ + \overrightarrow{\varepsilon}_t^{\prime} \text{ for } t = 1, \ldots, T$$

where

$$\begin{aligned} \overrightarrow{\mathbf{A}}_+^{\prime} &\equiv \begin{bmatrix} \overrightarrow{\mathbf{A}}_1^{\prime} & \cdots & \overrightarrow{\mathbf{A}}_p^{\prime} & \overrightarrow{\mathbf{D}} \end{bmatrix} \\ \overrightarrow{\mathbf{x}}_t^{\prime} &\equiv \begin{bmatrix} \overrightarrow{\mathbf{y}}_{t-1}^{\prime} & \cdots & \overrightarrow{\mathbf{y}}_{t-p}^{\prime} & \mathbf{w}_t^{\prime} \end{bmatrix} \end{aligned}$$

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 Akaike criterion information (AIC).

2.3 Identification of structural shocks

2.3.1 General task

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 do so, here we adopt a partial identification strategy. That is, since the model size $\left(\overrightarrow{n} = \dim \overrightarrow{\mathbf{y}}_t\right)$ is potentially big, the task of writing down a full structural identification procedure is far from straightforward (Zha, 1999). In turn, we emphasize the idea of partial identification, since in general we are only interested in a portion of shocks $\underline{n} < \overrightarrow{n}$ in the SVAR model, e.g. domestic and foreign monetary policy shocks. In this regard, Arias et al. (2014) provide an efficient routine to achieve identification through zero and sign restrictions. We adapt their routine for the case of block exogeneity.

2.3.2 The algorithm

The algorithm for the estimation is as follows[5]

1. Set first $K = 2000$ number of draws.
2. Draw $(\mathbf{B}^*, \mathbf{\Sigma}^*)$ from the posterior distribution (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 $\left((\mathbf{T}^*)^{-1}\mathbf{Q}^*, \mathbf{B}^*(\mathbf{T}^*)^{-1}\mathbf{Q}^*\right)$ satisfy the zero restrictions and recover the draw $(\mathbf{A}_0^*)_k = (\mathbf{T}^*)^{-1}\mathbf{Q}^*$.
4. Draw $(\mathbf{B}, \mathbf{\Sigma})$ from the posterior distribution (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 $\left(\mathbf{T}^{-1}, \mathbf{B}\mathbf{T}^{-1}\right)$ satisfy the zero restrictions and recover the draw $(\mathbf{A}_0)_k = \mathbf{T}^{-1}\mathbf{Q}$.
6. Take the draws $(\mathbf{A}_0)_k$ and $(\mathbf{A}_0^*)_k$, then recover the system (3) and compute the impulse responses.

[5] For details, see Arias et al. (2014).

7. If sign 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 two aspects related with this routine:

- In contrast with a Structural VAR estimated through Markov Chain Monte Carlo methods (Canova and Pérez, 2012), draws from the posterior are independent each other.

- Draws from the reduced form of the two blocks $(\mathbf{B}, \mathbf{\Sigma})$ and $(\mathbf{B}^*, \mathbf{\Sigma}^*)$ are independent by construction.

2.4 Identifying a QE shock

We approach the mechanism of transmission as it is estimated in the literature in both the big and the small open economy (the U.S. and Peru, respectively). We select those variables that allow a good representation of each economy (according to the relevant literature). We include for the U.S. economy: the economic policy uncertainty index, an interest rate spread between long- and short-term, M1, Federal Funds rate, the consumer price index, and the industrial production index. For Peru, we consider: the terms of trade, the real exchange rate, the interbank interest rate in domestic currency, banking system credit in U.S. dollars and in domestic currency, the consumer price index, and GDP.[6]

The purpose of this section is to estimate the effects of an U.S. QE shock over important macroeconomic variables in the Peruvian economy. Therefore, we first need to identify the mentioned structural shock within the big economy block. Then, we estimate the transmission of this shock free of any restriction in the small economy block in order to be completely agnostic about any spillover effect that this type of shocks may generate. In short, we impose that the QE shock generates an increase in money aggregates, a decrease in the yield curve spreads, and must keep the Federal Funds rate unchanged in the U.S. block while all other variables in the whole system are unconstrained (see Table 1 for sign restrictions).

Similar identification strategies for unconventional monetary policy shocks through sign restrictions can be found in Peersman (2011), Gambacorta et al. (2012), Baumeister and Benati (2012), Schenkelberg and Watzka (2013). In line with this literature, our QE shock candidate is identified using a mixture of zero and sign restrictions. Moreover, we impose that those sign restrictions must be satisfied for a horizon of three months.

2.5 Results

Results are depicted in Figures 3 and 4, where the shaded areas represent the sign restrictions. A QE shock increases the money stock (M1), reduces the level of the spread

[6] For more details of the data, see Apendix A.

Table 1. *Identifying Restrictions for a QE shock in the U.S.*

Variable	QE shock
Domestic block	?
U.S. economic policy uncertainty index (EPU_{US})	?
Term spread indicator (*Spread*)	−
M1 money stock ($M1_{US}$)	+
Federal Funds rate (FFR)	0
U.S. consumer price index (CPI_{US})	?
U.S. industrial production index (IP_{US})	?

Note: ? = left unconstrained.

between the long- and short-term interest rates (Spreads) and keeps the Federal Funds rate (FFR) at zero. Strictly speaking, this is an expansionary unconventional policy shock and, as a result, it produces a positive effect in industrial production (IP_{US}) and prices (CPI_{US}) in the U.S. economy.

These effects are significant in the short run and are in line with Peersman (2011), Gambacorta et al. (2012), Baumeister and Benati (2012), Schenkelberg and Watzka (2013). Moreover, it can also be observed that the effects on spreads are not persistent and tend to disappear quiete fast, in line with Wright (2012).

The QE shock previously identified is transmitted to the Peruvian Economy. We observe a real appreciation (RER) in line with the massive entrance of capital to the domestic economy. Moreover, the latter produces a credit expansion in both currencies ($Cred_{FC}$ and $Cred_{DC}$), and a positive response of the domestic interest rate (INT) in the medium run. There is not a clear effect over the terms of trade (TOT).

Finally, we register small responses of output (GDP) and prices (CPI), our variables of interest. These responses are positive and significant only in the medium run.

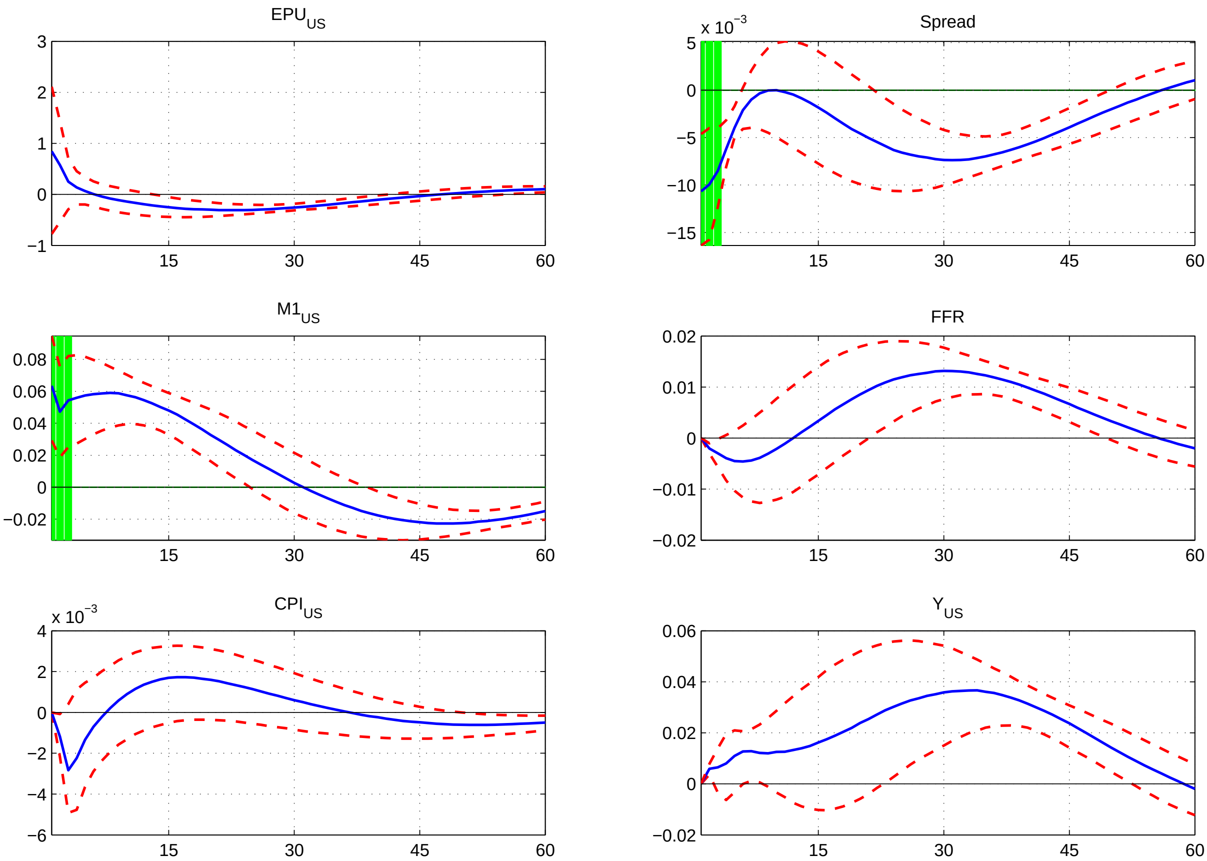
3 Counterfactual analysis

We follow the framework proposed by Pesaran and Smith (2012). They define a "policy effect" relative to the counterfactual of "no policy scenario". We first summarize this approach, then we test for policy effectiveness and finally present the ex-ante QE effects for the Peruvian economy.

3.1 The setup

Suppose that the policy intervention is announced at the end of the period T for the periods $T+1, T+2, ..., T+H$. The intervention is such that the "policy on" realized values of the policy variable are different from the "policy off" counterfactual values (what

Figure 3. *U.S. economic responses after a QE shock; median value and 66% bands*



would have happened in the absence of the intervention).

For that, define the information set available at time t as $\Omega_T = \{x_t \text{ for } t = T, T-1, T-2, ...\}$. Let m_t be the policy variable. The realized policy values are the sequence: $\Psi_{T+h}(m) = \{m_{T+1}, m_{T+2}, ..., m_{T+h}\}$. The counterfactual policy values are: $\Psi_{T+h}(m^0) = \{m^0_{T+1}, m^0_{T+2}, ..., m^0_{T+h}\}$.

Ex-ante policy evaluation can be carried out by comparing the effects of two alternative sets of policy values: $\Psi_{T+h}(m^0)$ and $\Psi_{T+h}(m^1)$. The expected sequence with "policy on" $\Psi_{T+h}(m^1)$ differ from the realized sequence $\Psi_{T+h}(m)$ (by implementation errors).

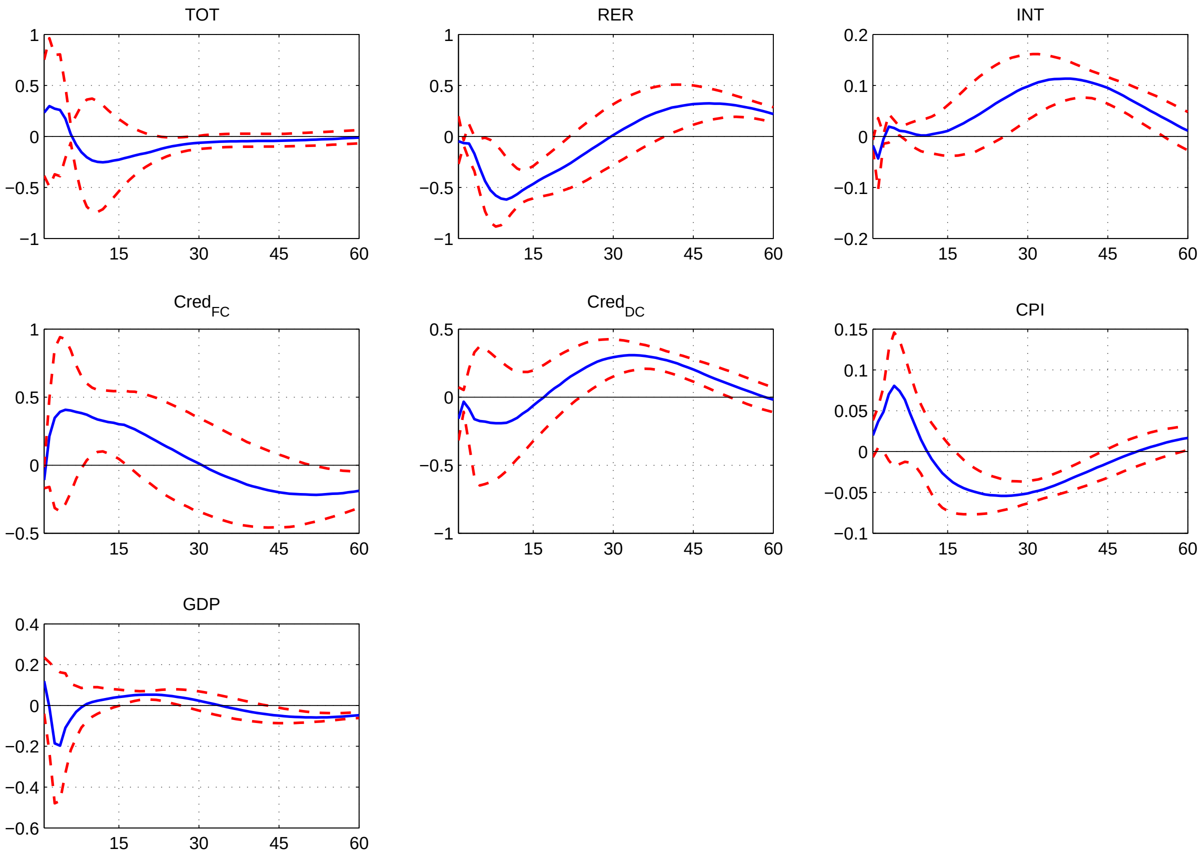
Hence, the ex-ante effect of the "policy on" $\Psi_{T+h}(m^1)$ relative to "policy off" $\Psi_{T+h}(m^0)$ is given by

$$d_{t+h} = E(z_{t+h}|\Omega_T, \Psi_{T+h}(m^1)) - E(z_{t+h}|\Omega_T, \Psi_{T+h}(m^0)),\ \ h = 1, 2, ..., H, \quad (7)$$

where z_t is one of the variables in the matrix x_t, except the policy variable(s).

The evaluation of these expectations depends on the type of invariances assumed. We assume that the policy form parameters and the errors are invariant to policy interventions.

Figure 4. *Peru economic responses after a QE shock; median value and 66% bands*



3.2 Test for policy effectiveness

It is important to determine to test the hypothesis that the policy had no effect. Pesaran and Smith (2012) address this issue.

Notice that the expected values of the policy variable given information at time t, may differ from the realizations because the implementation errors.

The procedure follows the next steps. First, calculate the difference between the realized values of the outcome variable in the "policy on" period with the counterfactual for the outcome variable with "policy off"

$$d_{t+h}^{ex-post} = z_{t+h} - E(z_{t+h}|\Omega_T, \Psi_{T+h}(m^0)), \; h = 1, 2, ..., H. \tag{8}$$

Unlike the ex ante measure of police effects, the ex post measure depends on the value of the realized shock, $\epsilon_{z,t}$. That is

$$d_{t+h}^{ex-post} = E(z_{t+h}|\Omega_T, \Psi_{T+h}(m^1)) - E(z_{t+h}|\Omega_T, \Psi_{T+h}(m^0)) + \epsilon_{z,t}, \; h = 1, 2, ..., H. \tag{9}$$

or

$$d_{t+h}^{ex-post} = d_{t+h}^{ex-ante} + \epsilon_{z,t}, \; h = 1, 2, ..., H. \tag{10}$$

Forecast errors in (10) will tend to cancel each other out. Therefore, the ex post mean of the policy is given by:

$$d_h = \frac{1}{H} d_{t+h}^{ex-ante}. \tag{11}$$

For a test of $d_h = 0$, Pesaran and Smith (2012) show that the policy effectiveness test statistic can be written as

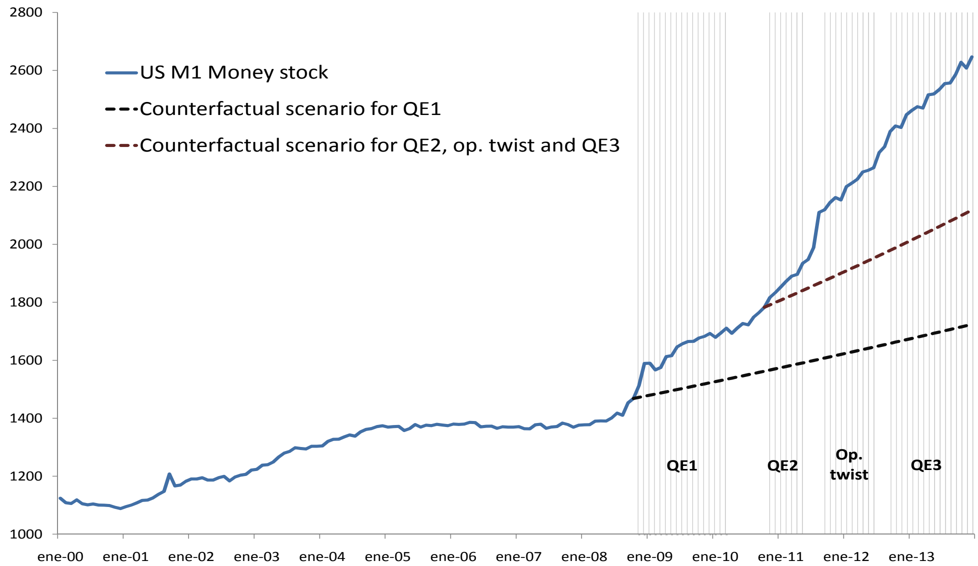
$$P_h = \frac{\widehat{d}_h}{\widehat{\epsilon}_{z,t}} \sim N(0,1), \tag{12}$$

where $\widehat{d}_h = \frac{1}{H}\widehat{d}_{t+h}^{ex-ante}$ is the estimated mean effect and $\widehat{\epsilon}_{z,t}$ is the estimated standard error of the policy form regression.

3.3 Counterfactual scenario

Figure 5 shows the U.S. M1 stock, the continued line is the realized sequence and the discontinued line is the counterfactual scenario. We consider an scenario in which the U.S. M1 stock grows at the same rate as in the period January 2002-October 2008.

Figure 5. *U.S. M1 Money Stock*



Source: FRED.

There is an important role for the terms of trade in the case of Peru. Castillo and Salas (2010) present evidence that suggest that this external variable is the most relevant for explaining Peruvian business cycles. If we consider that Glick and Leduc (2012) and Cronin (2013) present evidence in favor of positive effects of QE over terms of trade through asset pricing.

3.4 Ex-ante effects

As shown in Table 2, the effect of each QE program leads to an increase in capital inflow, a real exchange rate appreciation, a decrease in the GDP growth. In the second QE round (QE2), a decrease in the inflation and interest rates are expected.

Table 2. *QE effects throughout the U.S. M1 (keeping low the FED interest rate)*

	QE ex-ante effect		
	Median QE1	66% lower bound	66% upper bound
U.S. economy			
M1 Money stock (% change)	8.23	–	–
FED interest rate (p.p)	0.00	–	–
Econ. policy uncertainty	4.08	5.04	3.12
Term spread (p.p)	-0.19	-0.20	-0.17
Inflation rate (%)	0.95	0.92	0.97
Industrial production (%)	2.43	2.32	2.54
Peruvian economy			
Terms of trade (% change)	5.51	5.16	5.83
Exchange rate (% change)	-3.19	-3.39	-2.94
Interest rate (p.p)	-0.29	-0.35	-0.25
Credit in U.S. dollars (%)	6.41	6.13	6.65
Credit in Soles (%)	4.72	4.48	4.95
Inflation rate (%)	0.48	0.43	0.53
Activity growth (%)	0.21	0.11	0.35

Table 3. *FED Quantitative Easing dates*

	Start	Finish
QE 1	Nov-08	Mar-10
QE 2	Nov-10	Jun-11
Operation twist	Sep-11	Jun-12
QE 3	Sep-12	Jun-15

Note: The Finish date for QE 3 is estimated.

When we conduct a test of policy effectiveness, we find that most of the effects are not statistically significant. As Barata et al. (2013) notice, the test statistics has a low power if: (i) the policy horizon is too short relative to the sample, (ii) the policy effects are very short lived or (iii) the model forecasts very poorly.

Since each policy round included in this study covers a short time of period (6, 4, and 3 quarters in each round), the asymptotic approximation implicit in the testing procedure performs poorly. One possible solution is devising a bootstrap procedure to approximate the finite sample.

4 Conclusions and agenda

Our results suggest small effects of QE over key macroeconomic variables such as output and inflation in a SOE. The increase in international liquidity that follows after each QE seems to transmit its effects over the macro-economy of most SOE through channels such as interest rates, credit growth, and exchange rate. In that regard, most central banks in developing countries anticipated those effects and adopted macroprudential measures that mitigate any negative effect that may disseminate over their economies. Macroprudential tools that target credit growth (use of reserve requirements) and exchange rate volatility (use of interventions in the FOREX market) tend to exercise some control over how a QE event is transmitted to their economies.

The first empirical task we undertake is the estimation of a QE shock. In doing so, we estimate a SVAR with block exogeneity and sign restrictions in line with Zha, 1999. We aim at the identification of a monetary policy shock in the U.S. block that satisfies those characteristics present in a QE event. Then we estimate the dynamic impact of that shock over the Peruvian block, our SOE under analysis. The impulse-response exercise shows that there is statistically significant effects over financial variables such as exchange rate, credit in both domestic and foreign currency, and interest rates. We also find QE effects over inflation and output but those effects are small and only significant in the medium term.

We robust our result by running a counterfactual analysis in line with Pesaran and Smith (2012). We use our results from the SVAR in order to contrast two escenarios in which QE measures are either operating or not. On average, we find that the QE effect over inflation is -0.7 (-0.4 percent if U.S. term spread is considered) and over economic growth is 0.03 (0.08 if U.S. term spread is considered). This result is in line with our previous finding in the SVAR exercise.

The differentiated effect that exist between each QE round may bring up different results and a better identification strategy. Some researchers consider that QE1 was a rescue program while QE2 and QE3 were programs orientated to stabilize and secure a steady growth path. Even inside of each round, it is possible to split the different components for each QE round.[7] We leave in agenda a more detailed identification of each QE based on the composition of each program.

We are currently extending our sample of countries. Peru is a highly dollarized economy in terms of deposits and credit banking and that may play an important role in the transmission of the QE shock. Other Latin American countries such as Chile and Colombia that have lower levels of dollarization may have different responses to an external liquidity shock as it was the case of the QE shock.

[7] For example, QE1 was announced November 25, 2008 as a program to purchase agency debt and MBS in order to provide greater support to mortgage lending and housing markets for up to 600 billion U.S. dollars. This QE1 was expanded on March 18, 2009 and an additional 850 billion U.S. dollars of same securities were approved in addition to 300 billion U.S. dollars in long-term Treasuries.

The addition of variables that captures Macroprudential policies is also in agenda. Even though we argue that those effects are already captured by the variables that are intended to be targets of those policies, we may robust our results by excluding all financial variables and plug those variables that capture those macroprudential policies. For example, reserve requirements rather than credit or exchange rate interventions rather than exchange rate.

Some exercises over different measures of capital flows are also in order, specially long- versus short-term flows. Even though there is agreement of the massive capital inflows in the region, it is also true that central banks adopted Macroprudential measures that diminish the full effect of those incoming capitals. Then, it is important to distinguish those capitals and robust our result to the measure of capital flow under investigation.

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

References

Arias, J. E., J. F. Rubio-Ramírez, and D. F. Waggoner (2014, January). Inference Based on SVARs Identified with Sign and Zero Restrictions: Theory and Applications. Dynare Working Papers 30, CEPREMAP.

Barata, J., L. Pereira, and A. Soares (2013). Quantitative easing and related capital flows into brazil: Measuring its effects and transmission channels through a rigorous counterfactual evaluation. Technical report.

Baumeister, C. and L. Benati (2012). Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound. Technical report.

Belke, A. and J. Klose (2013). Modifying taylor reaction functions in presence of the zero-lower-bound: Evidence for the ecb and the fed. *Economic Modelling 35*(1), 515–527.

Bernanke, B. S. (2006, March). Reflections on the yield curve and monetary policy. Speech presented at the Economic Club of New York.

Canova, F. (2005). The transmission of US shocks to Latin America. *Journal of Applied Econometrics 20*(2), 229–251.

Canova, F. and F. Pérez (2012, May). Estimating overidentified, nonrecursive, time-varying coefficients structural VARs. Economics Working Papers 1321, Department of Economics and Business, Universitat Pompeu Fabra.

Carrera, C. (2011). El canal del credito bancario en el peru: Evidencia y mecanismo de transmision. *Revista Estudios Economicos* (22), 63–82.

Castillo, P. and J. Salas (2010). Los terminos de intercambio como impulsores de fluctuaciones economicas en economias en desarrollo: Estudio empirico.

Cronin, D. (2013). The interaction between money and asset markets: A spillover index approach. *Journal of Macroeconomics*.

Curdia, V. and M. Woodford (2011, January). The central-bank balance sheet as an instrument of monetarypolicy. *Journal of Monetary Economics 58*(1), 54–79.

Cushman, D. O. and T. Zha (1997, August). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics 39*(3), 433–448.

Eichengreen, B. (2013). Currency war or international policy coordination? *Journal of Policy Modeling 35*(3), 425–433.

Fratzscher, M., M. Lo Duca, and R. Straub (2013, June). On the international spillovers of us quantitative easing. Working Paper Series 1557, European Central Bank.

Gagnon, J., M. Raskin, J. Remache, and B. Sack (2011). Large-scale asset purchases by the federal reserve: did they work? *Economic Policy Review* (May), 41–59.

Gambacorta, L., B. Hofmann, and G. Peersman (2012, August). The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis. BIS Working Papers 384, Bank for International Settlements.

Glick, R. and S. Leduc (2012). Central bank announcements of asset purchases and the impact on global financial and commodity markets. *Journal of International Money and Finance 31*(8), 2078–2101.

Hamilton, J. D. and J. C. Wu (2012, 02). The effectiveness of alternative monetary policy tools in a zero lower bound environment. *Journal of Money, Credit and Banking 44*, 3–46.

Jones, C. and M. Kulish (2013). Long-term interest rates, risk premia and unconventional monetary policy. *Journal of Economic Dynamics and Control*, 2547–2561.

Lenza, M., H. Pill, and L. Reichlin (2010, 04). Monetary policy in exceptional times. *Economic Policy 25*, 295–339.

Ocampo, S. and N. Rodríguez (2011, December). An Introductory Review of a Structural VAR-X Estimation and Applications. BORRADORES DE ECONOMIA 009200, BANCO DE LA REPÚBLICA.

Peersman, G. (2011, November). Macroeconomic effects of unconventional monetary policy in the euro area. Working Paper Series 1397, European Central Bank.

Pesaran, M. H. and R. P. Smith (2012). Counterfactual analysis in macroeconometrics: An empirical investigation into the effects of quantitative easing. Technical report.

Quispe, Z. and R. Rossini (2011, Autumn). Monetary policy during the global financial crisis of 2007-09: the case of peru. In B. for International Settlements (Ed.), *The global crisis and financial intermediation in emerging market economies*, Volume 54 of *BIS Papers chapters*, pp. 299–316. Bank for International Settlements.

Rudebusch, G. D., B. P. Sack, and E. T. Swanson (2007). Macroeconomic implications of changes in the term premium. *Review* (Jul), 241–270.

Schenkelberg, H. and S. Watzka (2013). Real effects of quantitative easing at the zero-lower bound: Structural var-based evidence from japan. *Economic Policy 33*, 327–357.

Taylor, J. B. (2011). Macroeconomic lessons from the great deviation. In *NBER Macroeconomics Annual 2010, Volume 25*, NBER Chapters, pp. 387–395. National Bureau of Economic Research, Inc.

Walsh, C. E. (2010). *Monetary Theory and Policy, Third Edition*, Volume 1 of *MIT Press Books*. The MIT Press.

Wright, J. (2012). What does monetary policy do to long-term interest rates at the zero lower bound? *The Economic Journal*, 447–466.

Zha, T. (1999, June). Block recursion and structural vector autoregressions. *Journal of Econometrics 90*(2), 291–316.

A Data Description and Estimation Setup

We include raw monthly data for the period December 1998-December 2013.

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

We include the following variables from the U.S. economy:

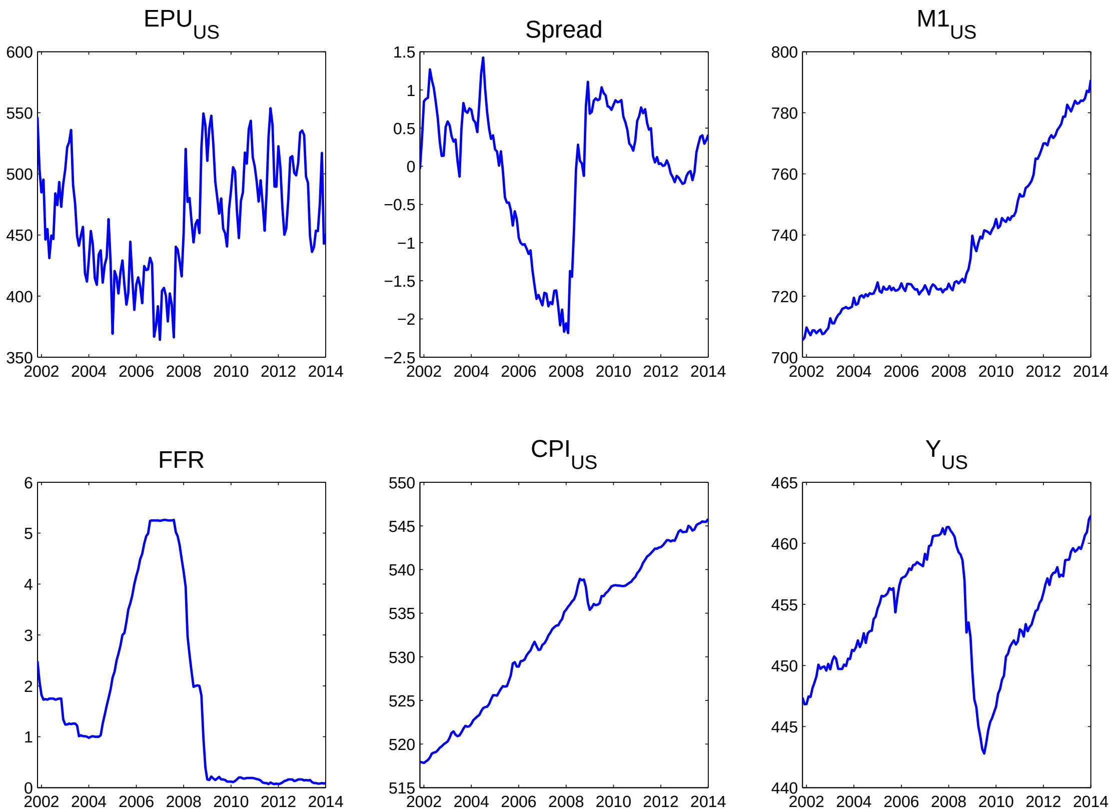
- Economic policy uncertainty index from the US (EPU_{US}).
- *Spread* indicator[8].
- M1 Money Stock, not seasonally adjusted.
- Federal Funds Rate (FFR).
- Consumer Price Index for All Urban Consumers: All Items (1982-84=100), not seasonally adjusted.

[8]This is calculated as the first principal component from all the spreads with respect to the Federal Funds Rate: 3M,6M,1Y,2Y,3Y,5Y,10Y,30Y from the treasury. In addition we include AAA,BAA, State Bonds and Mortgages.

- Industrial Production Index (2007=100), seasonally adjusted.

Data is in monthly frequency and it was taken from the Federal Reserve Bank of Saint Louis website (FRED database). Interest rates were taken from the H.15 Statistical Release of the Board of Governors of the Federal Reserve System website.

Figure 6. *US Time Series (in 100*logs and percentages)*



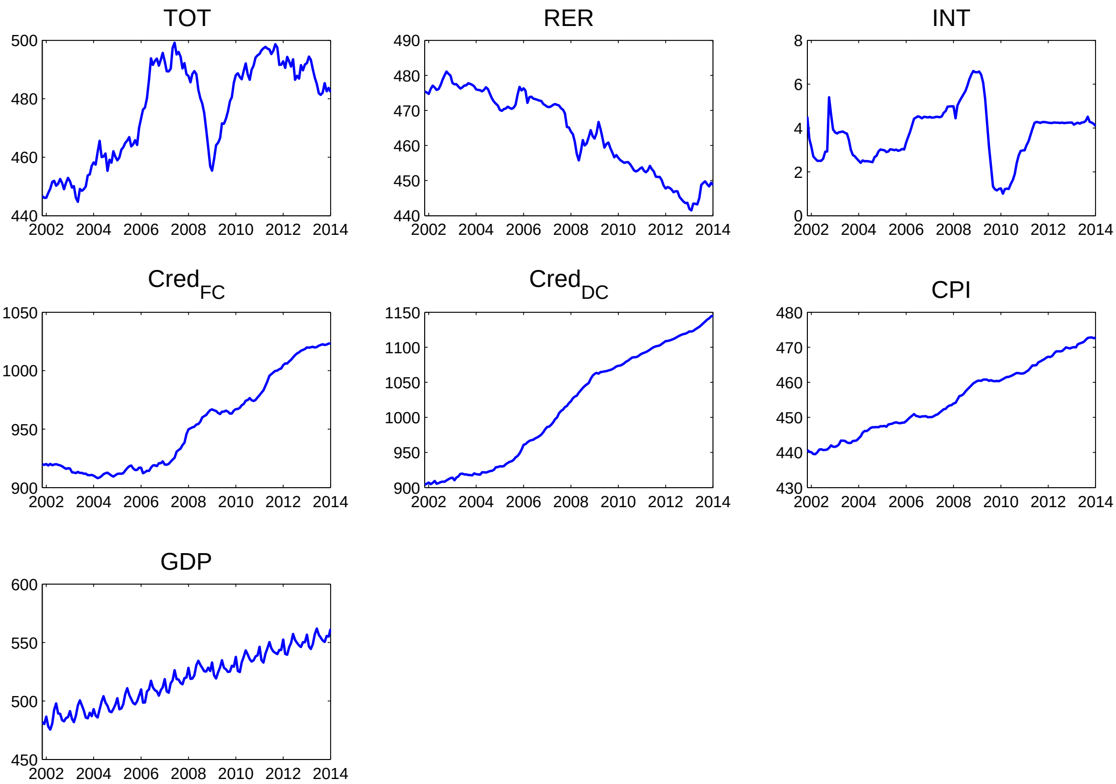
A.2 Small open economy block variables $\mathbf{y}_t$

We include the following variables from the Peruvian economy:

- Terms of trade.
- Real exchange rate.
- Interbank interest rate in nuevos Soles.
- Aggregated credit of the banking system in U.S. Dollars (Foreign Currency).
- Aggregated credit of the banking system in nuevos Soles (Domestic Currency).
- Consumer price index for Lima (2009=100).
- Real Gross Domestic Product index (1994=100).

Data is in monthly frequency and it was taken from the Central Reserve Bank of Peru (BCRP) website. All variables except interest rates 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.

Figure 7. *Peruvian Time Series (in 100*logs and percentages)*



A.3 Exogenous variables $\mathbf{w}_t$

- World commodity price index.
- Eleven seasonal monthly dummy variables.
- Constant and quadratic time trend (t^2)[9].

World commodity price index were obtained from the IFS database.

[9] The interactions of these trends with D_1 and D_2 are also included.

Figure 8. *Time Series included as exogenous variables (in 100*logs)*