Effects of the U.S. Quantitative Easing on the Peruvian Economy

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Preliminar version, April 2014

Abstract

Small open economies (SOE) 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 the Peruvian economy. In that regard, we first capture QE effects in a SVAR with block exogeneity (a la Zha, 1999) in which shocks to the U.S. economy have effects over the SOE but there is no effects in the U.S. from shocks in the SOE. Following the counterfactual analysis of Pesaran and Smith (2012), we further identify QE effects over domestic growth and inflation. We find small but significant effect over inflation and output 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 and how they have triggered large surges in capital inflows to emerging countries, leading to exchange rate appreciation, high credit growth, and asset price booms. Unconventional monetary policies are used by central banks in developed economies to stimulate their economies

We would like to thank Joshua Aizenman, Bluford Putnam, Liliana Rojas-Suarez, Marcel Fratzscher, and Michael Kamradt for valuable comments and suggestions. We also thank to the participants of the research seminar at the Central Bank of Peru, CEMLA-CME seminar in Bogota, Colombia. The views expressed are those of the authors and do not necessarily reflect those of the Central Bank of Peru. All remaining errors are ours.

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when standard monetary policy has become ineffective (when the short-term interest rate is at its zero lower-bound).

Walsh (2010) points out 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), instead they can exercise close control over narrow reserve aggregates such as the monetary base or very short-term interest rate. Those operating procedures (relationship between central bank instruments and operating targets) were very important in recent years in what is denominated QE.

A central bank that implements QE buys a specific amount of long-term financial assets from commercial banks, 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. Therefore, we use the sharp increase in international liquidity as a measure of the impact of QE. Figure (1) shows the policy rate close to zero, and how the spread between short and long term interest rate increases 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 (see Table 1 for specific dates of each QE round).

Table 1. *FED Quantitative Easing dates*

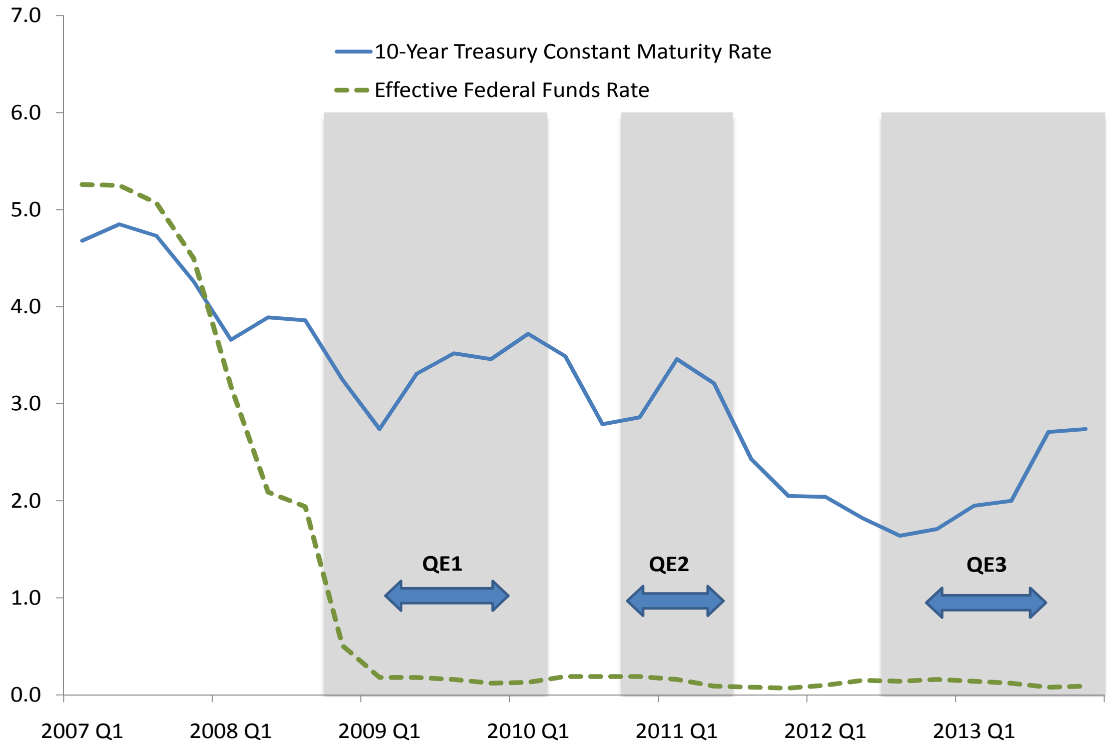
	Start	Finish
QE 1	Nov-08	Mar-10
QE 2	Nov-10	Jun-11
Operation twist	Sep-11	Jun-12
QE 3	Sep-12	Jun-14

Note: The Finish date for QE 3 is estimated.

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-term 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

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

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



Source: Federal Reserve Economic Data (FRED)

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. The expansion of the central bank's balance sheet through purchases of financial securities and announcements about future policy (influencing expectations) were usual instruments (see Belke and Klose 2013; Fratzscher et al. 2013; on theoretical grounds, see Curdia and Woodford 2011; also see Schenkelberg and Watzka 2013, for the case of Japan).

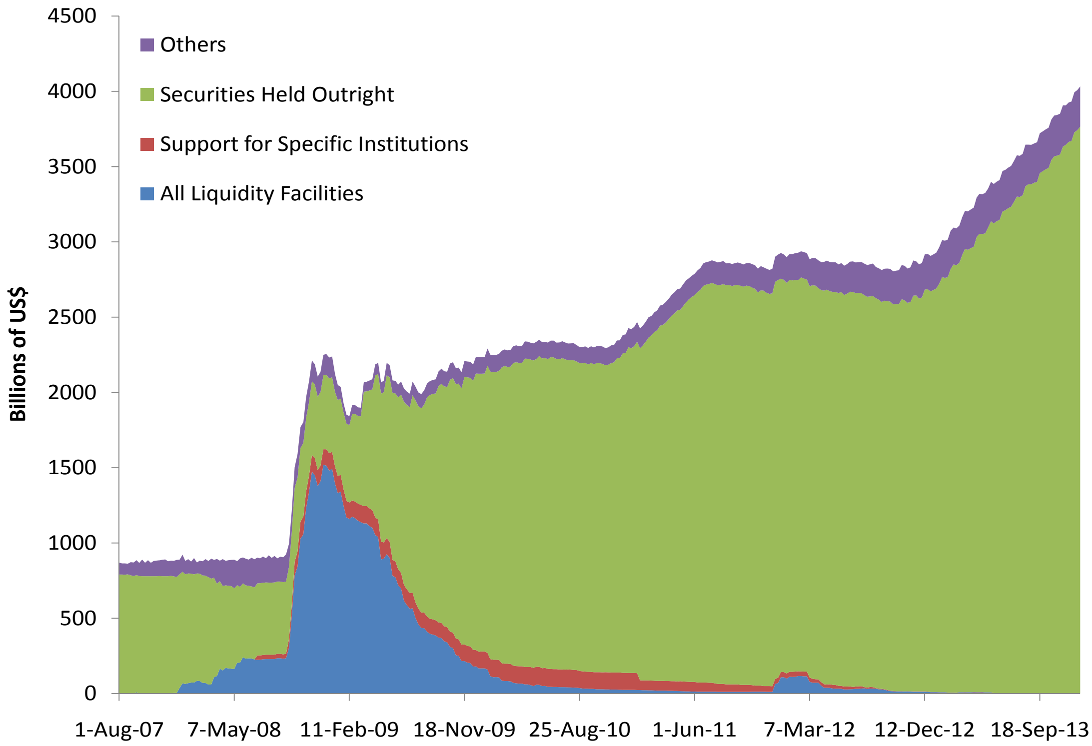
On the other hand, central banks from developing countries anticipated most negative effects from QE policies and adopted what is known as Macroprudential policies. The effects over exchange rate are discussed in Eichengreen (2013). The case of Peru is documented in Quispe and Rossini (2011).

In this regard, a vast literature has recently analysed the effectiveness of unconventional monetary policy measures[3] taken by central banks in both advanced and emerging

[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.

[3] Unconventional monetary policy are other forms of monetary policy that are used when interest

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



Source: Federal Reserve Economic Data (FRED).

economies. Policy-makers are interested in estimating the impact of a change in composition of central bank balance sheets on real 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 in line with Zha (1999). Our SVAR estimations are close to Baumeister and Benati (2012) who propose a sign restriction SVAR for the U.S. and the U.K. The advantage of block exogeneity is the transmission of the shocks: we model this system such a monetary policy shock in the U.S. has effects on the SOE and any shock from the SOE has no effects on the U.S. We then use our SVAR results and perform an ex-ante policy effects in line with Pesaran and Smith (2012).

The remaining of the paper is divided as follows: Section 2 presents the brief literature

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.

review of the state-of-the-art regarding QE policies and effects, Section 3 introduces the SVAR model with block exogeneity, Section 4 shows the counterfactual analysis, and Section 5 concludes.

2 Literature review

There are several papers that 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 (Jones and Kulish (2013), Hamilton and Wu (2012), Gagnon et al. (2011), and Taylor (2011)). 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 (Lenza et al. (2010) and Peersman (2011) for the case of Europe and Schenkelberg and Watzka (2013) for the case of Japan).

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.

2.1 Effect on OECD countries

For advanced economies, three of the largest advanced economies, the U.S., the U.K., and Japan, have implemented QE policy measures to boost their domestic economies. These have translated into lower long-term yields of Treasury bonds, as well as other financial assets through an imperfect substitution/ portfolio re-balancing channel. This, in turn, leads to an increase in asset prices and higher output growth.

Previous work has estimated limited spillover effects of QE policies on the rest of the world. In the IMF Spillover Report from 2013, there are estimates of a reduction of the one-year interest rate in 100 basis points and find that there is about 1.2 percent of output gain in the world economy, whereas spillovers from Japan and U.K. policy measures are not significant.

Glick and Leduc (2012) analyse the effects of the large scale asset purchases program on international financial asset prices, exchange rates, and commodity prices. They find that asset purchase announcements lower the 10-year U.S. Treasury yield and generate an exchange rate depreciation and a commodity prices fall.

A highly cited transmission mechanism of asset purchases to interest rates refers to the portfolio balance channel, where these policy measures reduce the supply of long-term securities for private investors and therefore increase securities prices and lower long term interest rates. A reduction in the yields of long-term Treasuries lower long-term interest rates, favoring an easing in financial conditions which leads to higher credit growth.

The liquidity channel refers to the substitution effect of purchasing assets from the private sector and providing higher market liquidity. This increases demand for all types of assets, leading to a boost in equity prices.

Another channel is through the effect on agents' expectations through signaling. Asset purchases signal a perception of worsening of economic conditions, with expectations of low short term interest rates to stay low in the near future. This, in turn, reduces long term interest rates.

2.2 Effect on emerging market economies

Our contribution is to analyse the spillover effects of QE policies in advanced economies on a broad set of macroeconomic variables of an emerging market. There has been some work that focuses on the spillover effects on emerging markets, but does not consider the particular case of a small open economy, as it is the case of Peru.

For instance, Barata et al. (2013) calculate the spillover effects of QE measures taken by the FED on the Brazilian economy. They use an extension of the counterfactual methodology proposed in Pesaran and Smith (2012) and find that the key channels through which these measures affect the Brazilian economy is through capital inflows, an exchange rate appreciation and a significant increase in credit growth.

Previous work identifies different channels through which QE policies affect emerging market economies. A key channel is the one that operates through portfolio re-balancing, given that emerging market bonds are imperfect substitutes of bonds issued by advanced economies. As long-term bond yields are quite low in advanced economies, international investors seek higher returns in emerging markets, especially in those with sound macroeconomic fundamentals. This effect translates into higher demand for emerging market bonds and lower long term interest rates in these countries as well.

Another important channel is the one related to liquidity, credit growth and asset prices. Increased global liquidity leads to investors searching for investment opportunities in emerging markets, which translates into surges of capital inflows to emerging economies. This induces higher credit growth and bank lending.

The exchange rate channel is also significant in the case of emerging economies, where surges in capital inflows lead to an appreciation of the domestic currency. Eichengreen (2013) describes the downward pressures on the exchange rate that may lead to central banks trying to reduce the volatility in foreign exchange rate market, by accumulating international reserves. If they are not fully sterilized, this boosts an increase in money supply and credit growth.

An alternative channel through which unconventional policies could affect emerging markets is through trade. By increasing output growth in advanced economies, this increases demand for exports from emerging markets. However, this effect is partially offset by an exchange rate appreciation. Cronin (2013) shades light for the interaction between money and asset markets under a financial asset approach.

3 A SVAR model with block exogeneity

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.

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

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.

3.2 Reduced form estimation

The system (3) is estimated by blocks. We first present a foreign and domestic block and later we introduce a compact form that stack the previous blocks.

3.2.1 Big economy block

The independent SVAR (1) can be written as

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

where

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

so that its reduced form representation is

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

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

3.2.2 Small open economy block

The SVAR (2) is written as

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

where

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

The reduced form is now

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

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

3.2.3 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

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

where

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

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).

3.3 Identification of structural shocks

3.3.1 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.

3.3.2 The algorithm

The algorithm for the estimation is as follows[4]

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.
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.

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

3.4 Identifying QE shocks

The purpose of this exercise is to evaluate the effects of U.S. QE shocks on the Peruvian economy. Therefore, we need first to identify the mentioned structural shock within the foreign block. Moreover, we are completely agnostic about the *spillover effects* that this type of shocks might generate on the Peruvian economy. In short, a QE shock generates an increase in money aggregates in the U.S., a decrease in the yield curve spreads and must keep the federal funds rate unchanged.

Table 2. *Identifying Restrictions for a QE shock in the U.S.*

Variable	QE shock
Domestic block	?
US economic policy uncertainty index ($\mathrm{EPU_{US}}$)	?
Term spread indicator (*Spread*)	$-$
M1 Money Stock ($\mathrm{M1_{US}}$)	$+$
Federal Funds Rate (FFR)	0
US consumer Price Index ($\mathrm{CPI_{US}}$)	?
US industrial Production Index ($\mathrm{IP_{US}}$)	?

Note: ? = left unconstrained.

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). As a result, the mentioned QE shock can be identified using a mixture of zero and sign restrictions, the ones. Moreover, sign restrictions that we propose must be satisfied for a three months horizon.

3.5 Results

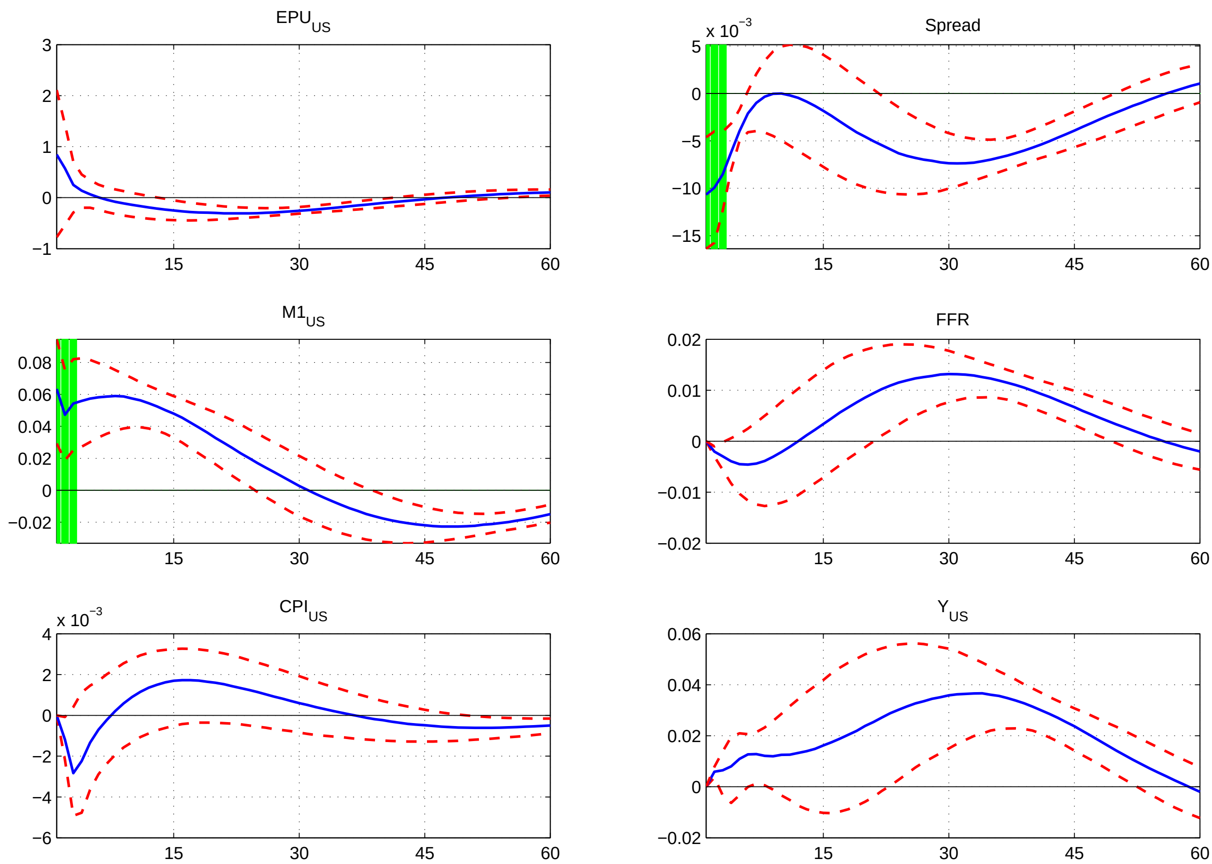
Results are depicted in Figures 3 and 4, where the shaded areas represent the sign restrictions. A QE shock increases the Money Stock (M1), reduces the level of the spread between the long and short term interest rates (Spreads) and keeps the Federal Funds Rate (FFR) at zero. Strictly speaking, this is an expansionary unconventional policy shock and, as a result, it produces a positive effect in Industrial Production ($\mathrm{IP_{US}}$) and Prices ($\mathrm{CPI_{US}}$) 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 die very fast, in line with Wright (2012).

Turning the effects on the Peruvian Economy, the QE shock produces 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 ($\mathrm{Cred_{FC}}$ and $\mathrm{Cred_{DC}}$) and a positive response of the domestic interest rate (INT) in the medium run. On the other hand, the terms of trade (TOT) rises.

Finally, small responses of output (GDP) and prices (CPI) are positive and significant only in the medium run.

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



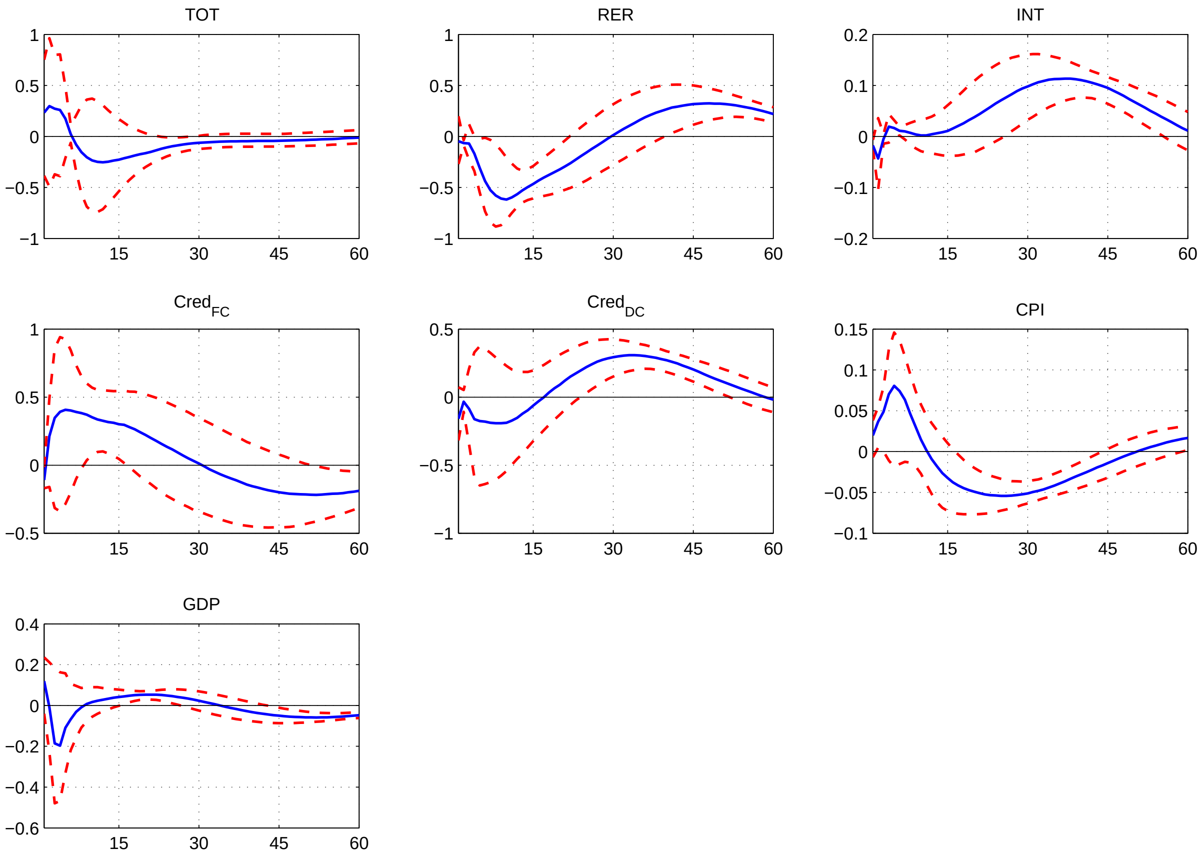
4 Counterfactual analysis

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.

4.1 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 would have happened in the absence of the intervention).

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



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

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

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.

4.2 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

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

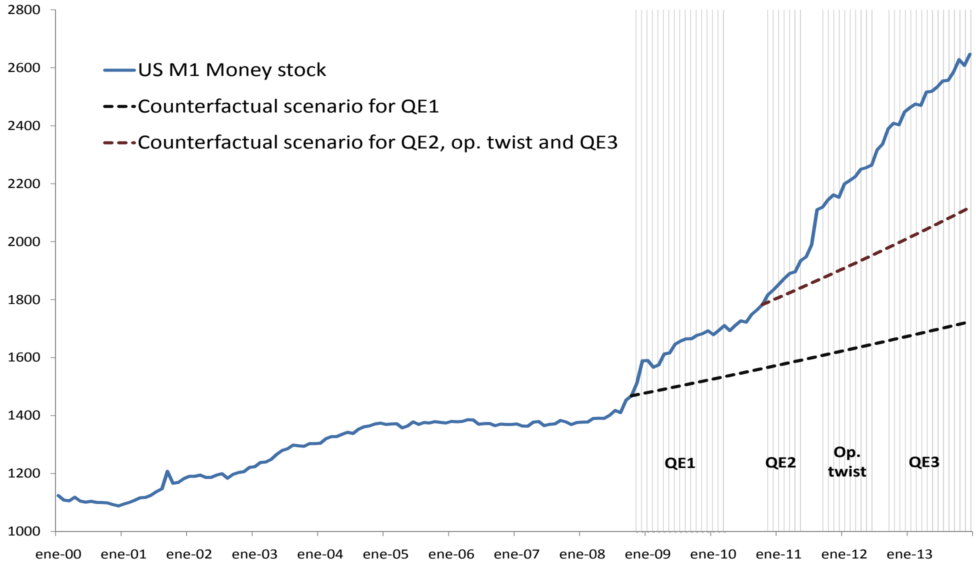
where $\widehat{d}_h = \frac{1}{H}\widehat{d}_{t+h}^{ex-ante}$ is the estimated mean effect and $\widehat{\epsilon}_{z,t}$ is the estimated standard error of the policy form regression.

4.3 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.

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.

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



Source: FRED.

4.4 Ex-ante effects

As shown in Table 3, 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.

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.

5 Conclusions and agenda

Following Pesaran and Smith (2012), our results suggest small effects of QE over key macroeconomic variables. The increase in international liquidity seems to transmit effects over the macro-economy through channels such as interest rates, credit growth, and exchange rate. In that regard, the central bank anticipated most of those effects and adopted macroprudential measures that mitigate any negative effect that may disseminate over the whole economy. Our results are consistent with this view, documented in

Table 3. *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

Quispe and Rossini (2011).

Macroprudential tools (such as reserve requirements) and control of exchange rate variability (in the case of interventions) tend to control most of the transmission mechanism that QE may have over the economy. This facts may explain why QE effect in average 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).

Some exercises over different measures of capital flows are also in order. Even though there is agreement of the 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.

It is also in agenda the measure of effects over lending. 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.

The base scenario requires a closer fine-tune. We need to consider other alternatives that give us more scenarios that central bank faces when there is not QE.

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A Data Description and Estimation Setup

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

A.1 Domestic block variables $\mathbf{y}_t$

We include the following variables from the Peruvian economy:

- Terms of trade.
- Real Exchange Rate.
- Interbank Interest Rate in Soles.
- Aggregated Credit of the Banking System in US Dollars (Foreign Currency).
- Aggregated Credit of the Banking System in Soles (Domestic Currency).
- Consumer Price Index for Lima (2009=100).
- Real Gross Domestic Product Index (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.

A.2 Foreign block variables $\mathbf{y}_t^*$

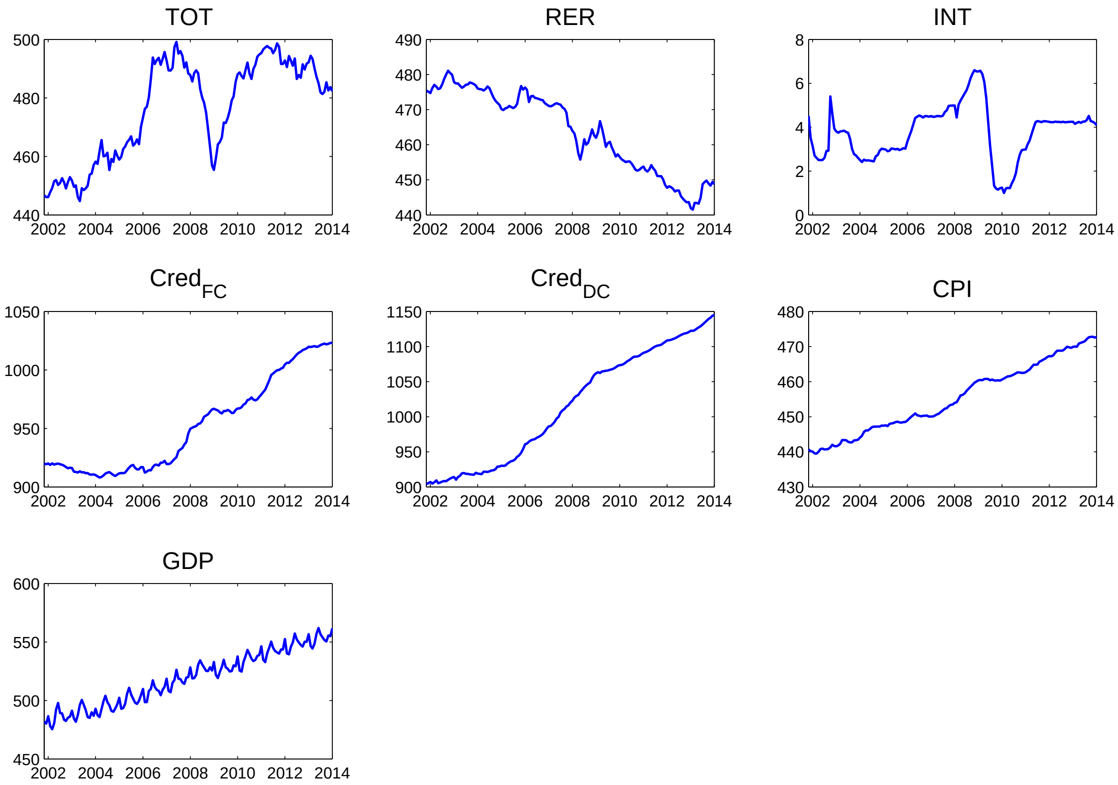
We include the following variables from the US economy:

- Economic policy uncertainty index from the US (EPU_{US}).
- *Spread* indicator[5].
- 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.
- Industrial Production Index (2007=100), seasonally adjusted.

Data is in monthly frequency and it was taken from the Federal Reserve Bank of ST. 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.

[5] 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.

Figure 6. *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)[6].

World commodity price index were obtained from the IFS database.

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

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

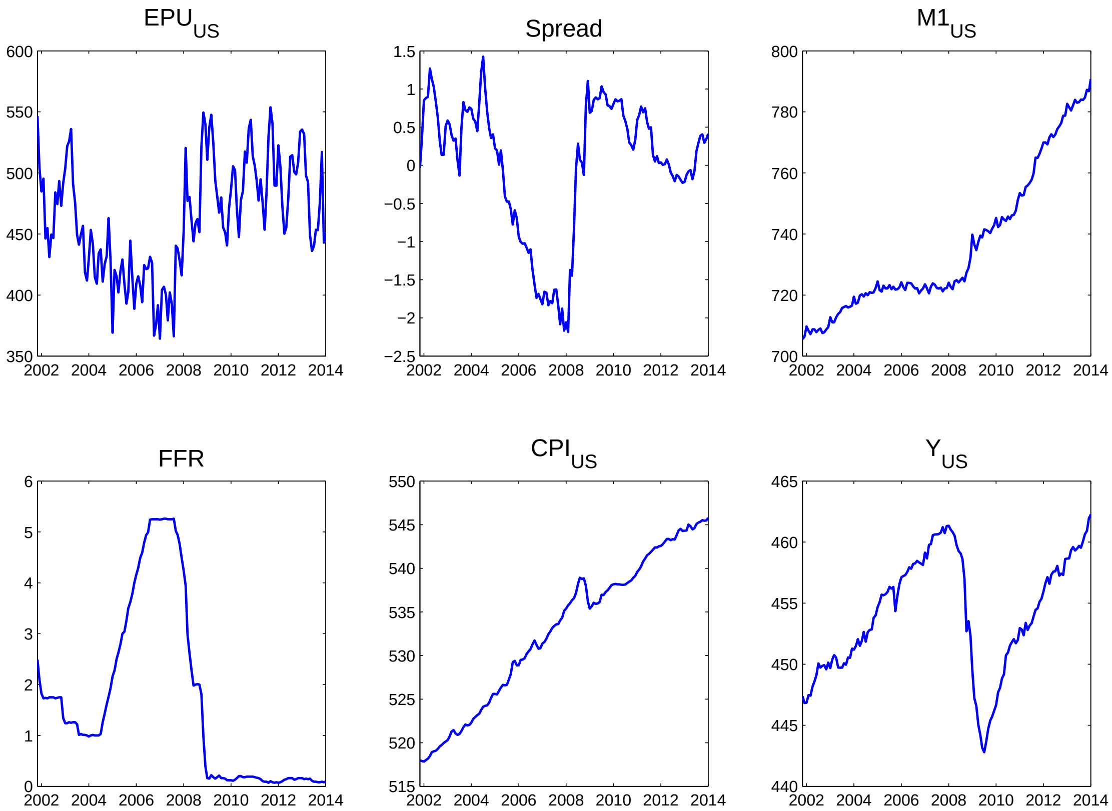


Figure 8. *Time Series included as exogenous variables (in 100*logs)*