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

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Abstract

Emerging economies were largely affected because of FED's quantitative easing (QE) policies. This paper assesses the impact of these measures in terms of key macroeconomic variables for a small open economy (SOE) such as Peru. We identify QE policy shocks in a SVAR with Block Exogeneity (*à la* Zha, 1999) and we impose a mixture of zero and sign restrictions (*à la* Arias et al., 2014). In addition, following Pesaran and Smith (2014), we implement a counterfactual exercise in order to gauge the differences between two scenarios: with and without QE policies. Overall, we find that QE policies had signifficant effects over financial variables such as aggregate credit and the exchange rate. On the other hand, we find small but significant effects over inflation and output in the medium run.

Resumen

Muchas economías emergentes fueron afectadas por las políticas de flexibilización cuantitativa (QE) de la Reserva Federal de los EEUU (FED). Este trabajo evalúa el impacto de dichas medidas sobre variables macroeconómicas en una econoía pequeña y abierta como Perú. Se identifican los choques de QE en un modelo SVAR con exogeneidad por bloques (*à la* Zha, 1999), se imponen restricciones de ceros y signos (*à la* Arias y otros, 2014). Asimismo, siguiendo a Pesaran y Smith (2014), se implementa un ejercicio contrafactual con el fin de estimar la diferencia entre dos escenarios: con y sin política de flexibilización cuantitativa. Se encuentra efectos significativos de estos choques sobre variables financieras tales como el tipo de cambio y el crédito. De otro lado, se encuentran efectos significativos sobre el producto y los precios en el mediano plazo, aunque de menor magnitud en relación a las variables financieras.

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Keywords: Quantitative Easing, Structural Vector Autoregressions, Sign Restrictions, Counterfactual analysis.

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1 Introduction

There has been widespread concern among policy-makers in emerging economies about the effects of Quantitative Easing (QE) policies implemented in developed economies. This comes from the fact 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 mentioned effects were transmitted to economic activity and inflation and, if any, we do not know how is the propagation mechanism of these shocks. The latter is related to the fact that most central banks in these economies have implemented macroprudential policies with the purpose of mitigate any potential systemic risk.

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

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 of those assets. Furthermore, QE may be used by monetary authorities for stimulating 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).

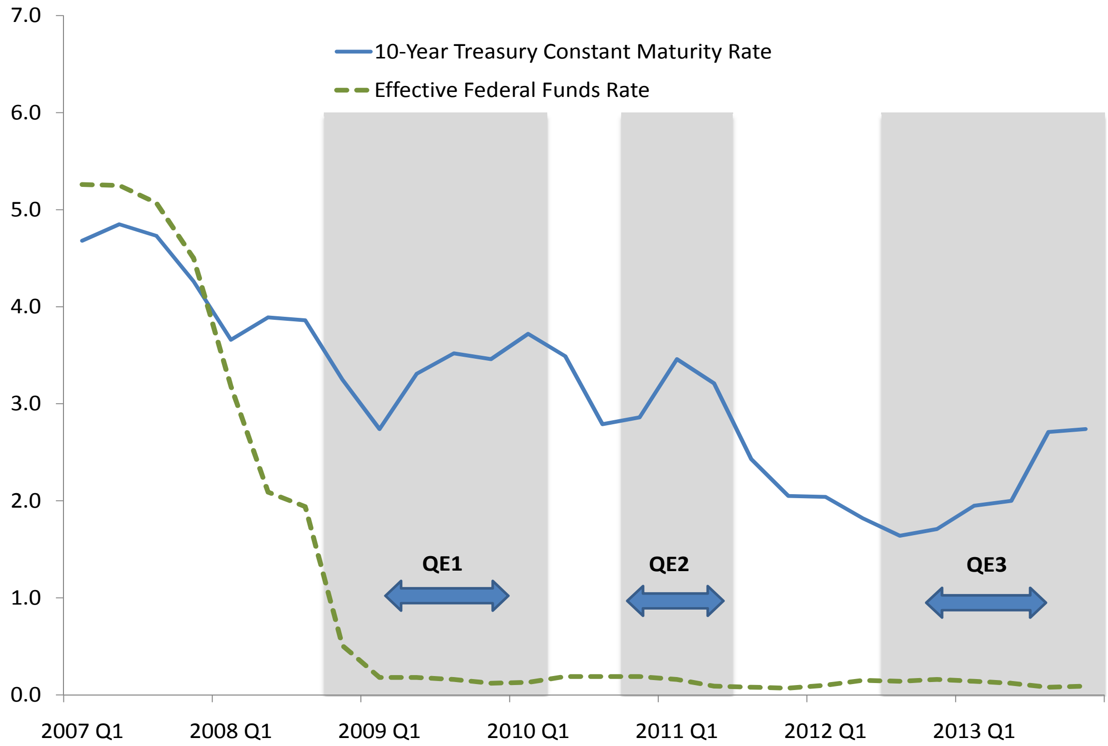
Regarding the U.S. and the Fed, QE policy measures increased the private sector liquidity, mainly through the purchase of long-term securities. That is, the QE episode in the U.S was characterized by a sharp increase in the size of the balance sheet of the Fed, together with an increase in money aggregates (e.g. M1), a decrease in the long versus short interest rates spread, and a short-term interest rate unchanged and very close to zero. Figure 1 depicts 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 at the same date.[1] Figure 2 depicts the evolution of Fed's balance sheet components. In particular, we can observe the switch towards securities, especially of Mortgage-Backed Security (MBS) and long-term Treasury bonds at the early November 2008.

According to Baumeister and Benati (2012), unconventional policy interventions in the treasury market narrowed the spread between long- and short-term government bonds. The latter triggered an increase in economic activity and 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. Even more, Bernanke (2006) argues that 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.[2]

[1] 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.

[2] Rudebusch et al. (2007) provides empirical evidence for a negative relationship between the term

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



Source: Federal Reserve Economic Database (FRED).

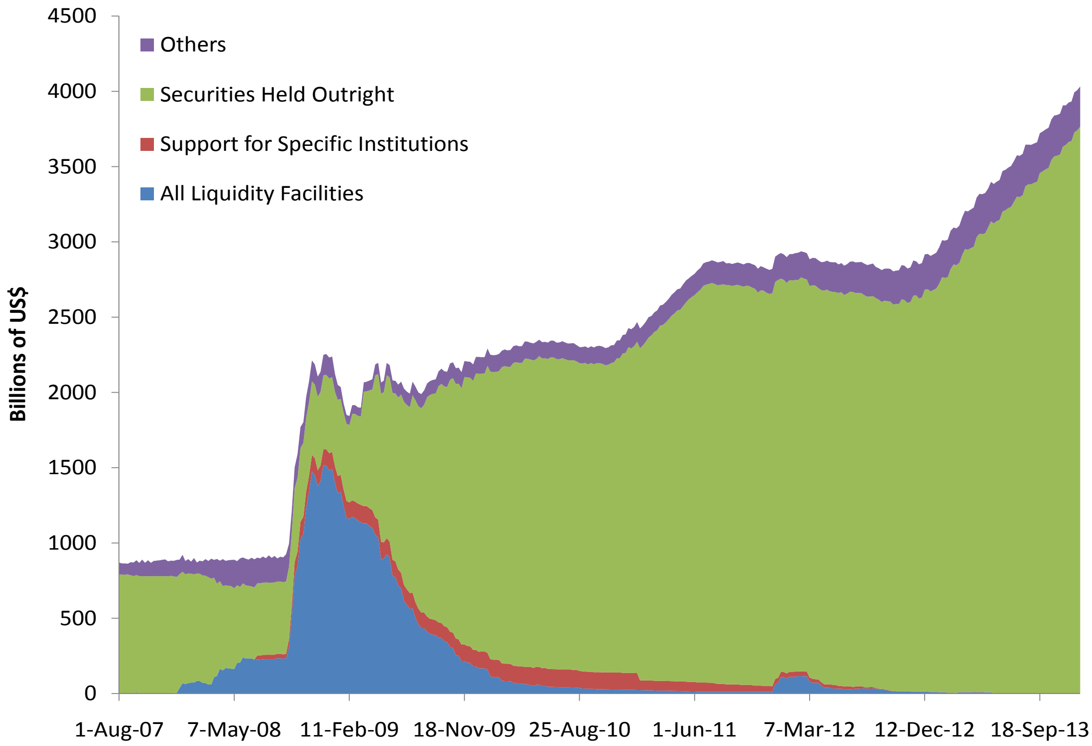
Starting in 2009, Central banks in the U.S., U.K., Canada, Japan, and the Euro area reduced their policy rates close to the zero lower bound (ZLB). At the same time, these institutions used alternative policy instruments and adopted macroprudential measures focused in close monitoring and supervision of financial institutions. Financial stability became one of the 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) analyze the effects of QE policy on the global economy. However, most of them focus their attention to financial variables such as long-term interest rates and aggregate credit. There are some other authors that analyze the QE policy effects on other key macroeconomic variables within the same economy: Glick and Leduc (2012) study the case of the U.S.; Lenza et al. (2010)

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 measures are other forms of monetary policy that are used when interest rates are very close the ZLB. These measures include QE policy, credit easing and signaling. Regarding credit easing, a central bank purchases private sector assets in order to improve liquidity and credit access. The Signaling policy is referred to Central Bank communication, i.e. the use of statements with the purpose of lowering market expectations of 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 Database (FRED).

and Peersman (2011) study the Euro Area; and Schenkelberg and Watzka (2013) cover the case of Japan. Gambacorta et al. (2012) perform a similar analysis for eight advanced 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) quantify the QE policy effects in the U.S. and in the U.K. Finally, Curdia and Woodford (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. The purpose of these policies was to affect financial variables such as exchange rates, capital flows, credit markets and asset prices.[4]

In this regard, a branch of the literature has analyzed the effectiveness of unconventional monetary policy measures taken by central banks in both advanced and emerging economies. In particular, policy makers are interested in assessing the impact of QE policies on output and inflation. However, little has been done for considering the spillover effects of these policy measures to emerging market economies.

[4] The effects over the exchange rate are discussed in Eichengreen (2013). See also Cronin (2013) for the interaction between money and asset markets and its effect on emerging economies. See Aizenman et al. (2014) for the effect of tapering over financial variables in developing economies. Moreover, the case of Peru is documented in Quispe and Rossini (2011).

This paper focus its attention on the macroeconomic effects of QE policy measures implemented by the FED over the Peruvian economy, i.e. over a small open economy (SOE). To do that we estimate a Structural Vector Autorregressive (SVAR) model with block exogeneity in the spirit of Zha (1999). Moreover, we identify QE policy shocks through a mixture of Zero and Sign Restrictions in the spirit of Arias et al., 2014. Given the identified shock, we assess how it is transmitted to the domestic block (Peruvian economy). The advantage of our approach is the fact that, by construction, U.S. shocks can affect Peruvian Economy but not the other way around.

Regarding the methodology, the list of previous papers that study other types of credit easing policies using SVAR models includes Schenkelberg and Watzka (2013), where they analyze the real effects of QE measures on the Japanese economy using zero and sign restrictions. They find that a QE policy shock generates a 7 percent drop in long-term interest rates and a 0.4 percent increase in industrial production. Baumeister and Benati (2012) estimate a Time-Varying SVAR identified through sign restrictions. They find that compressions in the long-term yield spread exert a powerful effect on both output growth and inflation in the U.S. and in the U.K.

The second part of our empirical strategy presents a counterfactual exercise, where we compare two scenarios: (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 (2014). Conditional on the evolution of key variables, we evaluate the impact of QE measures over Peruvian macroeconomic variables.

The structure of the paper is as follows: section 2 presents the SVAR model with block exogeneity and its results, section 3 presents the counter-factual exercise and section 4 concludes.

2 A SVAR model with block exogeneity

In this section we closely follow Cushman and Zha (1997) and Zha (1999). They argue that block exogeneity in a SVAR is a natural extension for small open economies, since it rules out any unrealistic effects that could arise in a standard SVAR model, e.g. a significant effect in the big economy derived from a shock in the small one. Furthermore, the assumption of block exogeneity reduces tremendously the number of parameters to be estimated. Finally, we estimate the model using bayesian techniques

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 for $t = 1, ..., T$ by

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

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

The small open economy is represented by

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

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

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

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

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 $\overrightarrow{\mathbf{y}}_t' \equiv \left[\begin{array}{cc} \mathbf{y}_t' & \mathbf{y}_t^{*\prime} \end{array}\right]$, $\overrightarrow{\mathbf{A}}_i \equiv \left[\begin{array}{cc} \mathbf{A}_i & \widetilde{\mathbf{A}}_i^* \\ \mathbf{0} & \mathbf{A}_i^* \end{array}\right]$ for $i = 1, \ldots, p$, $\overrightarrow{\mathbf{D}} \equiv \left[\begin{array}{c} \mathbf{D} \\ \mathbf{D}^* \end{array}\right]$ and $\overrightarrow{\varepsilon}_t' \equiv \left[\begin{array}{cc} \varepsilon_t' & \varepsilon_t^{*\prime} \end{array}\right]$.

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), among others. Moreover, it turns out that this is a plausible strategy for representing small open economies such as the Latin American ones, since they are influenced by external shocks like the mentioned Unconventional Monetary Policy (UMP) measures implemented 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

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

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

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

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

The SVAR (2) is written as

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

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

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

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 Rodriguez, 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

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

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

$$\overrightarrow{\mathbf{y}}_t^{\prime} = \overrightarrow{\mathbf{x}}_t^{\prime}\overrightarrow{\mathbf{B}} + \overrightarrow{\mathbf{u}}_t^{\prime} \quad \text{for } t = 1, \ldots, T \tag{6}$$

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).

2.2.4 Priors

We adopt Natural conjugate priors for reduced form coefficients. The latter implies that the prior, likelihood and posterior come from the same family of distributions (Koop and Korobilis, 2010). The introduction of priors is desirable, since the number of parameters to be estimated is very high and the number of observations is limited. Therefore, this a plausible strategy for reducing the amount of posterior uncertainty and, at the same time, it is useful for disciplining the data. In this regard, it is important to remark that we introduce priors for the reduced form coefficients, but the this does not mean that we impose any prior information about the structural form. The latter is out of the scope of this paper. Nevertheless, more details can be found in Canova and Perez Forero (2012) and Baumeister and Hamilton (2013).

We assume that the prior distribution of the object $\left(\mathbf{B}, \mathbf{\Sigma}^{-1}\right)$ is Normal-Wishart, so that

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

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

$$\underline{S} = \underline{h} I_n, \quad \underline{V} = I_K$$

with $\underline{h}$ being a hyperparameter and K the number of regressors. As a result, the posterior distribution is

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

where

$$\overline{V} = \left[\underline{V}^{-1} + \sum_{t=1}^{T} \mathbf{x}_t \mathbf{x}'_t\right]^{-1}$$
$$\overline{\mathbf{B}} = \left[\underline{\mathbf{B}}\underline{V}^{-1} + \widehat{\mathbf{B}}\left(\sum_{t=1}^{T} \mathbf{x}_t \mathbf{x}'_t\right)\right] \overline{V}$$

and

$$\begin{aligned} \overline{S} &= \sum_{t=1}^{T} \widehat{\mathbf{u}}_t \widehat{\mathbf{u}}'_t + \underline{S} + \widehat{\mathbf{B}}\left[\sum_{t=1}^{T} \mathbf{x}_t \mathbf{x}'_t\right] \widehat{\mathbf{B}'} + \underline{\mathbf{B}}\underline{V}^{-1}\underline{\mathbf{B}}' \\ &\quad - \overline{\mathbf{B}}\left[\underline{V}^{-1} + \sum_{t=1}^{T} \mathbf{x}_t \mathbf{x}'_t\right] \overline{\mathbf{B}}' \\ \overline{\nu} &= T + \underline{\nu} \end{aligned}$$

We apply the same procedure for the two estimated blocks in order to produce draws of $(\mathbf{B}, \mathbf{\Sigma})$ from its posterior distribution.

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.
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 Perez Forero, 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.

[5] See Arias et al. (2014).

2.4 Identifying a QE policy shock

In this section we assess the transmission mechanism of a structural QE policy shock. We first consider the U.S. as the big economy and Peru as the small one. Regarding the U.S. we include the variables: i) economic policy uncertainty index (EPU), ii) an indicator related with the spread between long and short-term interest rates (SPREAD), iii) a money aggregate (M1), iv) the Federal Funds Rate (FFR), v) the consumer price index (CPI), and vi) the industrial production index (IP). Regarding the Peruvian economy we include the variables: i) the terms of trade index (TOT), ii) the real exchange rate (RER), iii) the interbank interest rate in domestic currency (INT), iv-v) the aggregate credit of the banking system in U.S. dollars and in domestic currency, vi) the consumer price index (CPI), and the gross domestic product (GDP).[6]

We identify the QE shock imposing minimal restrictions in the U.S. economy block. On the other hand, we do not impose any restriction in the Peruvian economy block, since at this point we are completely agnostic about the endogenous spillover effects that can be generated by this shock. In short, we identify a QE shock such that it increases the level of U.S. money aggregates and, at the same time, decreases the level of spreads in the yield curve spreads keeping the Federal Funds Rate unchanged because of the Zero Lower bound (see Table 1).

Table 1. *Identification Restrictions for a QE policy 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.

Similar identification strategies for unconventional monetary policy shocks through sign and zero restrictions can be found in Peersman (2011), Gambacorta et al. (2012), Baumeister and Benati (2012), 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 three month horizon. One aspect that deserves to be mentioned is the flexibility of our identification scheme. In this regard, since we do not know the true model that contains this shock, we capture the parameter region that satisfy our restrictions, which might include several different structural models. On top of that, our QE policy shock is such that the monetary policy instrument might be either the money aggregate or the term spread. For that reason, we do not normalize the shock to one particular variable, since the is no consensus in the literature about the key policy instrument.

[6]See Appendix A for details regarding the transformations, etc.

2.5 Results

Results are depicted in Figures 3 and 4, where the shaded areas depict the sign restrictions. A QE policy 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) close to zero. Strictly speaking, this is an expansionary unconventional policy shock and, as a result, it produces a positive and significant effect in the industrial production (IP_{US}) and prices (CPI_{US}) in the medium run.

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 effect on spreads is not persistent and vanishes rapidly, in line with Wright (2012).

The identified QE policy shock 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. On the other hand, terms of trade (TOT) decreases in the medium run. Finally, we register smaller responses of output (GDP) and prices (CPI) relative to the financial variables. These responses are positive and significant in the medium run.

Figure 3. *U.S. economic responses after a QE policy shock; median value and 68% bands*

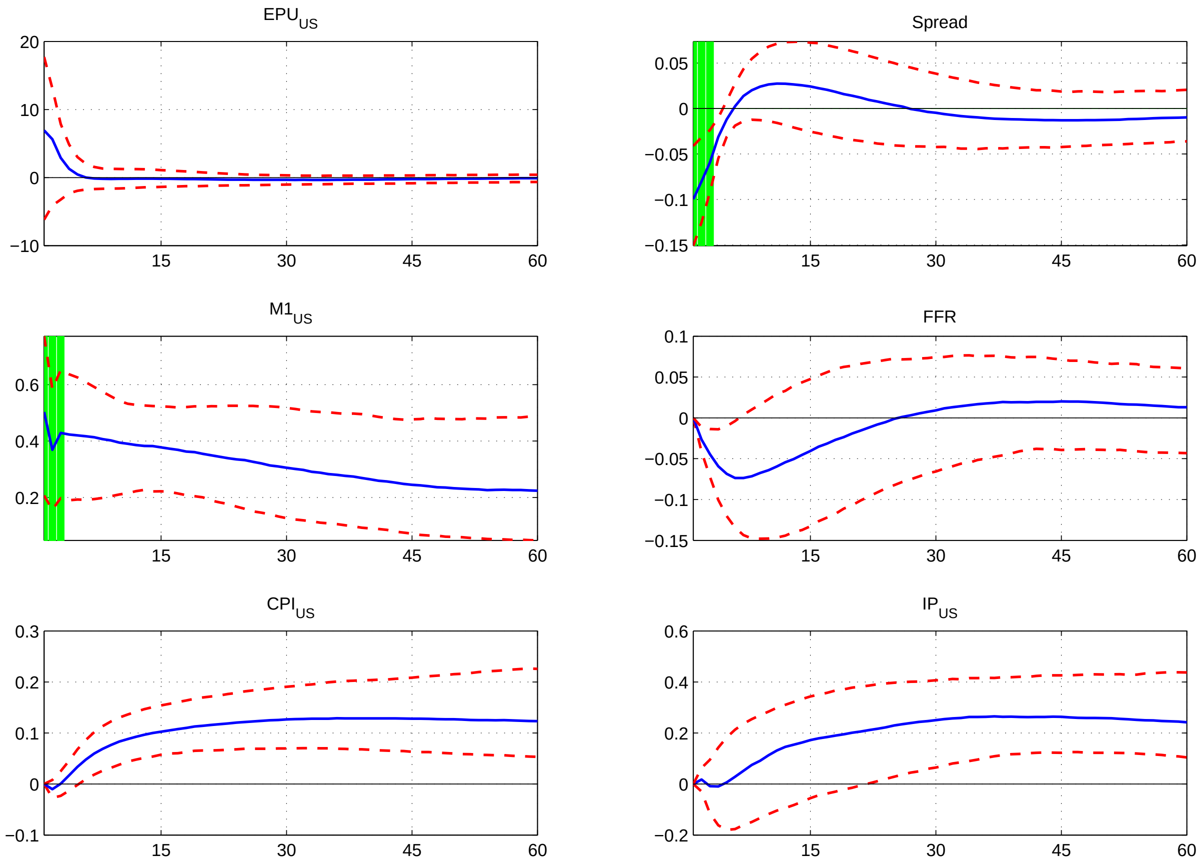
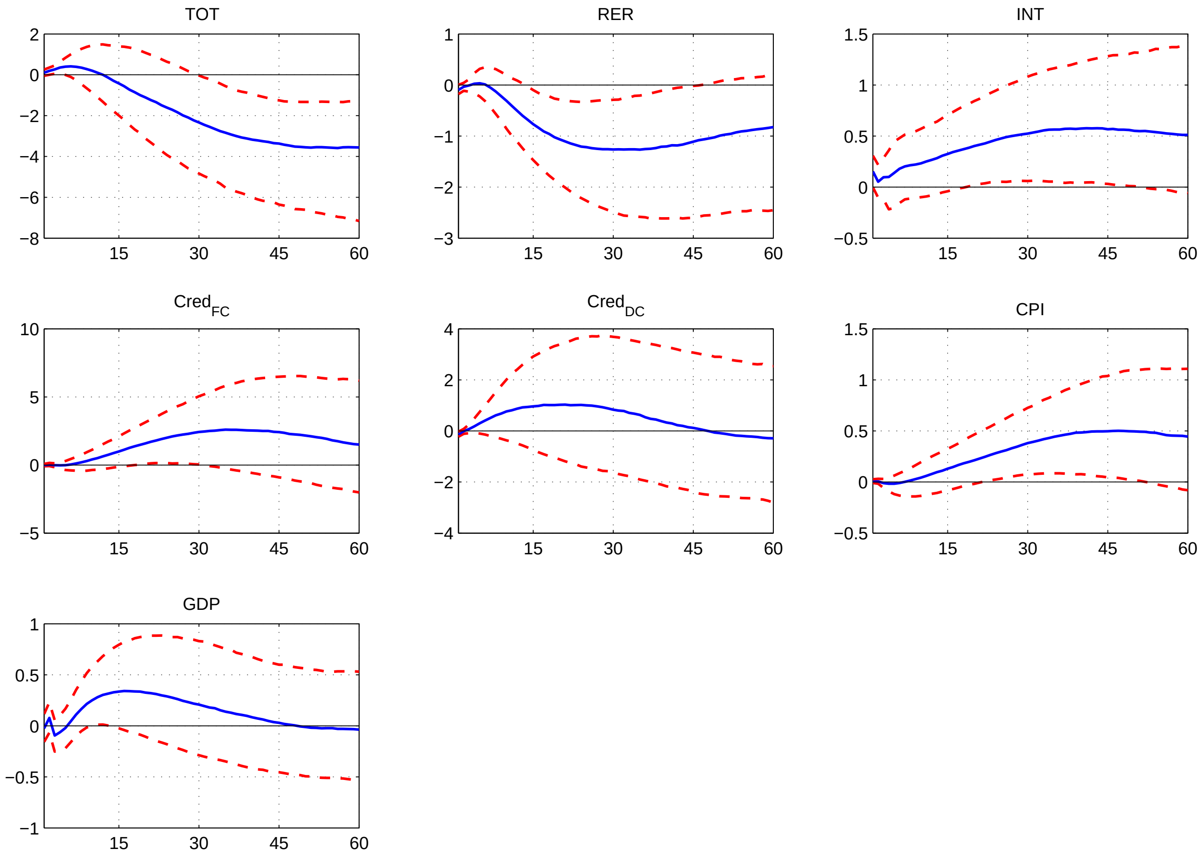


Figure 4. *Peru economic responses after a QE policy shock; median value and 68% bands*



3 Counterfactual analysis

In this section we closely follow the framework proposed by Pesaran and Smith (2014). 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 would have happened in the absence of the intervention).

In order to implement the experiment, define the information set available at time t as $\Omega_T = \{x_t \text{ for } t = T, T-1, T-2, ...\}$ and 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 invariance assumed. In particular, we assume that the policy form parameters and the errors are invariant to policy interventions.

We estimate the policy effects from the two-block SVAR model (1). The forecasts from the model will be used to estimate the policy effects.

3.2 A Test for policy effectiveness

It is important to test whether the hypothesis that the policy had no effect is true or not. Pesaran and Smith (2014) 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 (2014) show that the policy effectiveness test statistic can be written as

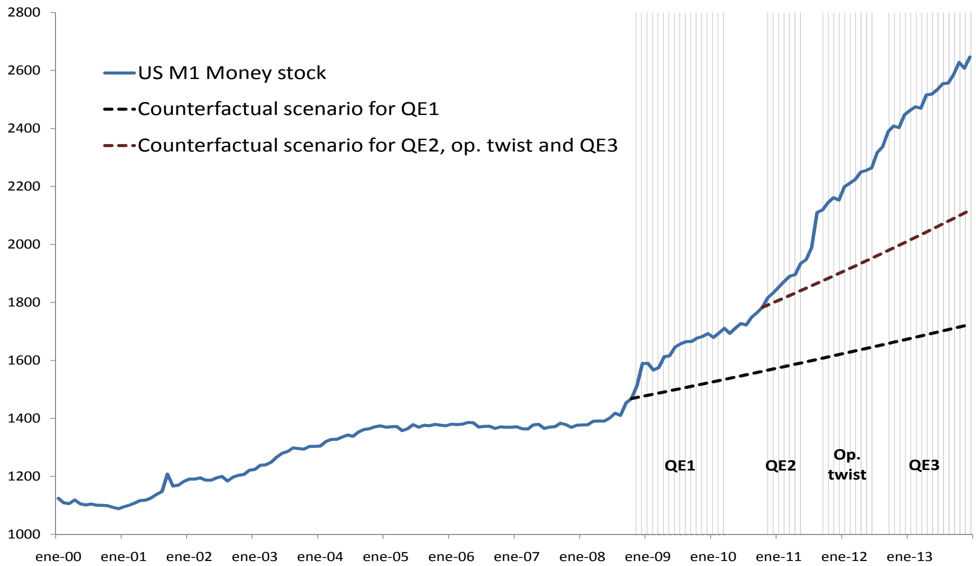
$$P_h = \frac{\widehat{d}_h}{\widehat{\epsilon}_{z,t}} \sim N(0, 1), \tag{12}$$

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

We conduct a test of policy effectiveness and we find that most of the effects are not statistically significant. As Barata et al. (2013) noticed, the test statistics have limited 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 amount of time (6, 4, and 3 quarters in each round respectively), the asymptotic approximation implicit in the testing procedure performs poorly. One possible solution is devising a bootstrap procedure to approximate the finite sample.

Table 2. *QE effects throughout the M1 in the U.S.(keeping the FFR close to zero)*

	QE ex-ante effect		
	Median QE1	66% lower bound	66% upper bound
U.S. economy			
M1 Money stock (% change)	9.98	–	–
FED interest rate (p.p)	0.00	–	–
Econ. policy uncertainty	-25.70	-33.77	-17.44
Term spread (p.p)	-0.19	-0.20	-0.17
Inflation rate (%)	0.70	0.27	1.11
Industrial production (%)	3.29	2.39	4.13
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's QE policy 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 final date for QE 3 is estimated.

Since we made 2000 draws of the reduced form parameters of the two-block SVAR, we can compute 2000 values of policy effectiveness and thereby test whether QE policies are statistically significant on key Peruvian macroeconomic variables.

4 Concluding Remarks

We identify a structural QE policy shock in an otherwise standard SVAR model. We quantify the effects derived from this shock to the U.S. economy and its transmission to the Peruvian economy. Our results suggest smaller effects of QE policy over output and inflation relative to financial variables in a small open economy (SOE). The increase in international liquidity that follows after each QE round seems to transmit its effects over the macroeconomy of the SOE through financial variables such as interest rates, credit growth, and exchange rates. In this regard, most central banks in developing countries anticipated those effects and adopted Macro-prudential policy measures. Macro-prudential tools pointed towards credit growth (via reserve requirements) and exchange rate volatility (via Foreign Exchange Intervention) and tended to mitigate the effects of a QE policy event.

We also perform robustness checks to our empirical strategy by running a counter-factual analysis, in line with Pesaran and Smith (2014). We use the previous results from the SVAR in order to contrast two scenarios in which QE policy measures are either operating or not. On average, we find that the QE policy 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).

The differentiated effect that exists 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 oriented 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.

Our research agenda is vast. 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 policy 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.

The inclusion of variables that measure Macro-prudential policies in the SVAR model is also part of our research 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 robustify our results by excluding all financial variables and plug those variables that capture those Macro-prudential policies. For example, reserve requirements rather than credit or exchange rate interventions rather than the exchange rate itself.

[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.

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 Macro-prudential 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.

The evaluation of QE policy effects over the lending channel is also part of our research agenda. 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.

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A Data Description and Estimation Setup

We include raw monthly data for the period October 1995 - December 2013.

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

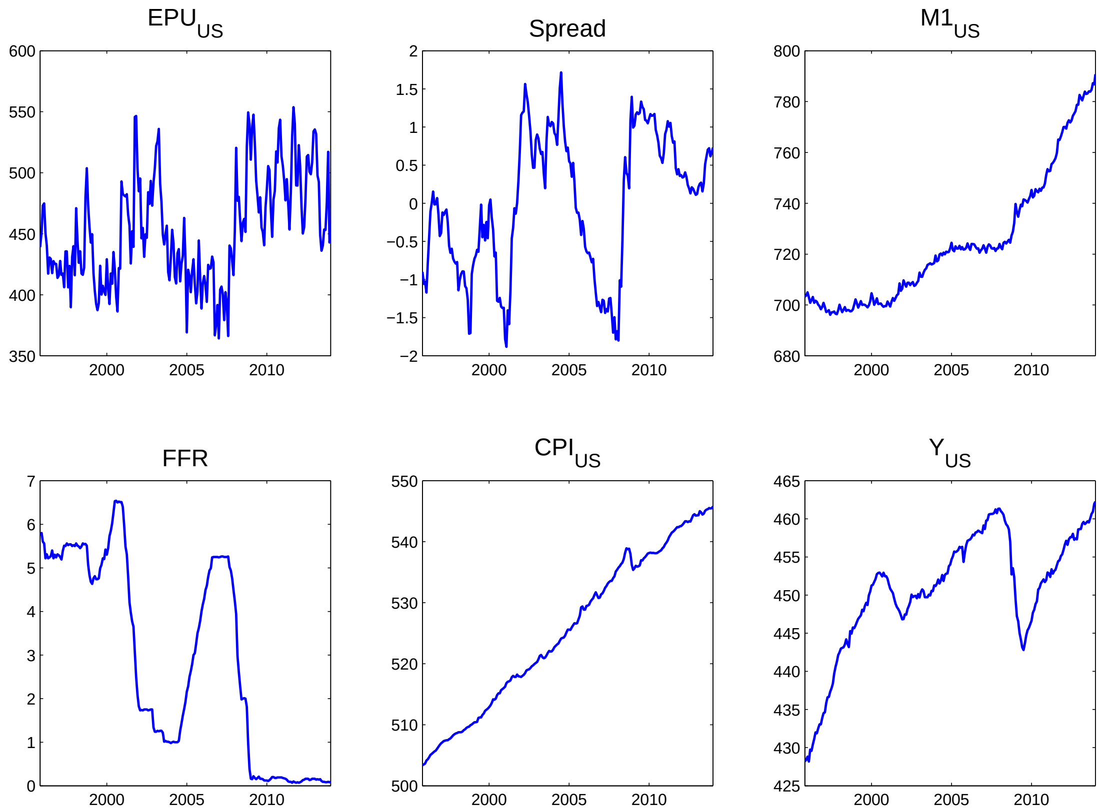
We include the following variables from the U.S. economy:

- 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.
- 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.

[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.

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:

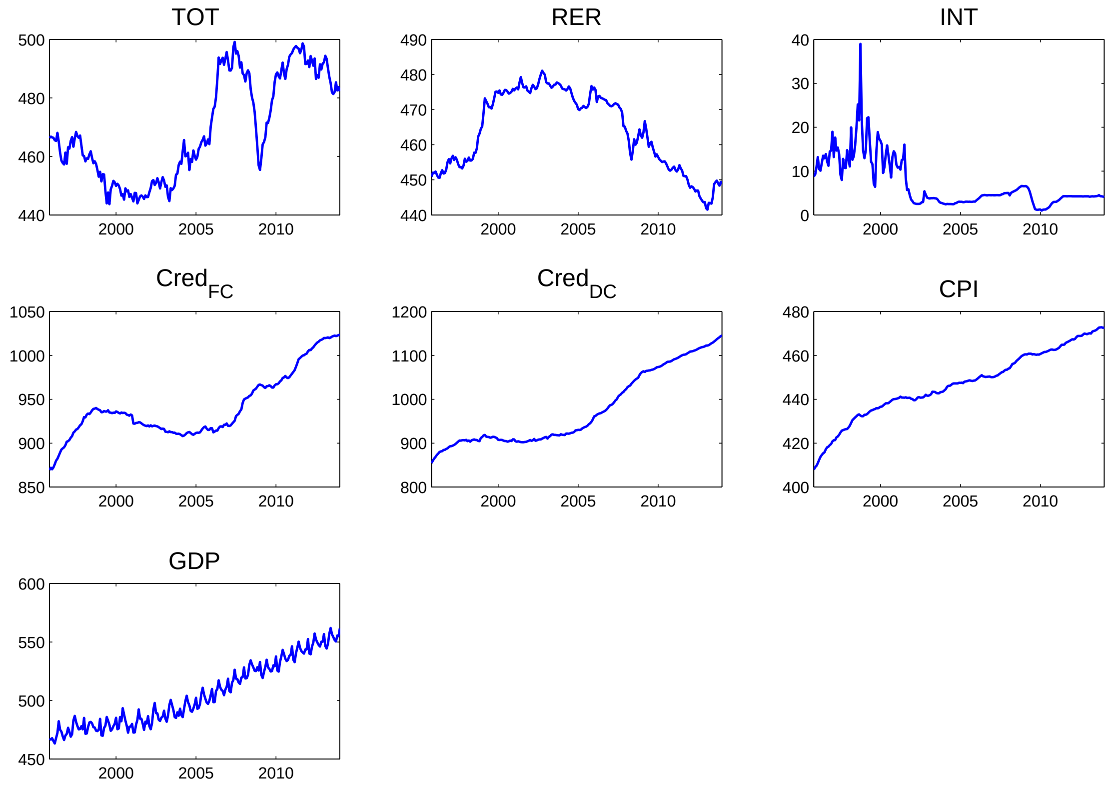
- Terms of trade.
- Real exchange rate.
- Interbank interest rate in nuevos Soles.
- Aggregated credit of the banking system in U.S. Dollars (Foreign Currency).
- Aggregated credit of the banking system in nuevos Soles (Domestic Currency).
- Consumer price index for Lima (2009=100).
- Real Gross Domestic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

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

- World commodity price index.

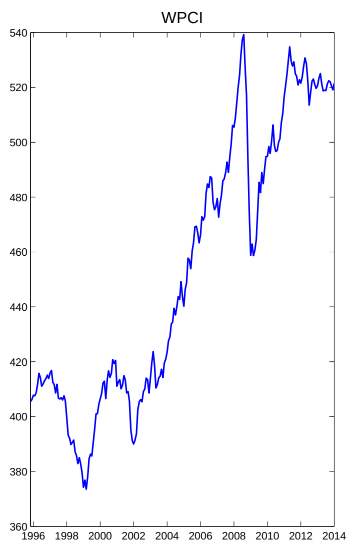
Figure 7. *Peruvian Time Series (in 100*logs and percentages)*



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

World commodity price index were obtained from the IFS database.

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



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