Effects of US Quantitative Easing on Emerging Market Economies*

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Abstract
This paper estimates international spillover effects of US Quantitative Easing (QE) on emerging market economies. Using a Bayesian VAR on monthly US macroeconomic and financial data, we first identify the US QE shock with non-recursive identifying restrictions. This identified shock is then used in another Bayesian VAR for emerging market economies to infer the international spillover effects on these countries. We find that an expansionary US QE shock has significant, if temporary, effects on financial variables in emerging market economies. It leads to an exchange rate appreciation, a reduction in long-term bond yields, and a stock market boom in both the “Fragile Five” and other emerging market economies. Apart from positive effects on equity flows and a reduction in net exports for some of the “Fragile Five” countries, we do not find significant effects of the US QE shock on other macroeconomic variables of emerging market countries such as output and consumer prices.

Keywords: US Quantitative Easing; Spillovers; Emerging Market Economies; Bayesian VAR; Non-recursive Identification; Fragile Five Countries

JEL Classification: C31; E44; E52; E58; F21; F41; F42

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1 Introduction

As a countercyclical response to the financial crisis and the onset of the Great Recession in 2007, the Federal Reserve drastically cut the short-term interest rate, the conventional monetary policy instrument. Once the short-term interest rate hit the zero lower bound at the end of 2008 however, the Federal Reserve engaged in unconventional monetary policy, buying long-term government bonds and private sector assets. This policy, referred to as quantitative easing, greatly affected the size and composition of the balance sheet of the Federal Reserve and was meant to provide further monetary stimulus to the economy by lowering long-term interest rates, even though the short-term nominal interest rate was stuck at the zero lower bound.\(^1\) In this paper, we evaluate the international spillover effects of the quantitative easing program of the Federal Reserve by assessing its impact on emerging market economies.

There has been an active and influential empirical literature, e.g. Gagnon et al (2011), Krishnamurthy and Vissing-Jorgensen (2011), and Neely (2010), trying to assess rigorously the effects of such large-scale asset purchase program on interest rates, expected inflation, and other asset prices such as exchange rates.\(^2\) The dominant approach in this literature is to assess the “announcement effects” of such policies, i.e. the response of high-frequency financial market variables to the Federal Reserve’s announcements of policy changes within a very narrow time frame, such as one or two days. By focusing on a narrow time window and isolating the changes in these variables due to the announcement of quantitative easing policy, this literature has shown that such policies most likely contributed to lowering long-term US interest rates and depreciating the US Dollar.

We contribute to this literature by taking an alternate complementary approach. We identify the effects of quantitative easing using an identified vector auto regression (VAR), in a manner similar to that widely used for assessing the effects of conventional monetary policy.\(^3\) This allows us to extend the insights from the announcement effects literature by

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\(^1\) The decision to purchase large volumes of assets by the Federal Reserve came in three steps, known as QE1, QE2 and QE3 respectively. On November 2008, the Federal Reserve announced purchases of housing agency debt and agency mortgage-backed securities (MBS) of up to $600 billion. On March 2009, the FOMC decided to substantially expand its purchases of agency-related securities and to purchase longer-term Treasury securities as well, with total asset purchases of up to $1.75 trillion, an amount twice the magnitude of total Federal Reserve assets prior to 2008. On September 2011, the Federal Reserve announced a new program on Operation Twist that involved purchasing $400 billion of long-term treasury bonds by selling short-term treasury bonds. This program was further extended in June 2012 till the end of the year. On September 2012, the last round of quantitative easing was announced, which consisted of an open ended commitment to purchase $40 billion mortgage backed securities per month. On December 2012, this program was expanded further by adding the purchase of $45 billion of long-term treasury bonds per month. Quantitative easing officially ended on October 2014.

\(^2\) An incomplete list of other papers in this literature is Hamilton and Wu (2012), Wright (2011), and Bauer and Rudebusch (2013).

\(^3\) In taking a VAR based approach to assess the effects of QE, our paper is related to Baumeister and Benati (2013), Gambacorta et al (2014), and Wright (2012). Our identification approach is however, different.
both assessing the impact on broader macroeconomic variables that policymakers focus on, such as output and consumer prices, as well as ascertaining the dynamic effects of such policy. Moreover, while there is work assessing the international effects of U.S. quantitative easing policy, e.g. Glick and Leduc (2012, 2013), Chen et al (2011), and Bauer and Neely (2013), we focus on the effects on emerging market economies. In doing so, we are particularly motivated by the reports in media and policy circles regarding the spillover effects on financial markets of emerging markets, both during the ongoing phase of the quantitative easing program as well as its tapering and eventual end.\(^4\) In this respect, while using very different empirical methods, we are contributing in the same vein as Eichengreen and Gupta (2013) and Aizenman et al (2014). Finally, given our results on equity flows, our work is related to Dahlhaus and Vasishtha (2014) and Lim et al (2014), who also analyzed the effects of US unconventional monetary policy on capital flows to developing/emerging market economies using a different approach to identification and inference.

In implementing our approach, we use several measures of the asset side of the Federal Reserve’s balance sheet as a measure of the unconventional policy instrument since 2008, with security held outright as our baseline measure.\(^5\) Moreover, in this context, we propose and use new identification strategies that allow us to separate the exogenous changes in quantitative easing policy from the endogenous changes of policy in response to the state of the economy. The approach is broadly motivated by the existing VAR literature that identifies a conventional monetary policy shock, in particular the identification approach of Sims and Zha (2006 a,b).

We first estimate an identified Bayesian VAR using monthly US data on both macroeconomic and financial variables. In our baseline estimation, we identify a strong impact of a positive shock to the asset holdings of the Federal Reserve on both US output and prices as well as robust evidence of reduction in US long-term Treasury yields and an increase in stock prices. In an extension, we also provide evidence of reduction in US corporate and mortgage yields as well as a depreciation of the US Dollar and an increase in US house prices. Thus, our results for the impact of QE on financial variables are consistent with the finding of the announcement effect literature, and moreover, our VAR specification allows us to document a strong macroeconomic impact.

Given the identified QE shock from the estimated baseline US VAR, we estimate a separate Bayesian VAR involving macro and financial variables for each of the emerging markets,

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\(^4\) For example, the so called “taper scare” of April 2013 had a major effect on capital flows and exchange rate of emerging market countries. For a case-study based survey on spillovers to emerging market economies, see Lavigne et al (2014).

\(^5\) In this sense our approach is similar to that of Gambacorta et al (2014) who focused on domestic implications, on some macroeconomic variables, of quantitative easing by several countries using a central bank balance sheet variable as an instrument of policy. Our identification method as well as the empirical focus is however, different as we detail later.
in which the US QE shock is treated as an exogenous variable. We estimate international spillover effects of the US QE shock on the following important emerging market economies: Chile, Colombia, Brazil, India, Indonesia, Malaysia, Mexico, Peru, South Africa, South Korea, Taiwan, Thailand, and Turkey.\(^6\) First, we focus on results on the so-called “Fragile Five” countries: Brazil, India, Indonesia, Turkey, and South Africa, and then analyze whether our results differ for the rest of the emerging economies. Our results show a strong and largely robust effect of the US QE shock on financial variables, in particular, on exchange rates and long-term interest rates. We find that a positive US QE shock appreciates these foreign currencies and drives down foreign long-term government yields. We also find suggestive evidence that a positive US QE shock drives up stock prices in these emerging market economies. These effects are common across all of the emerging market countries, although the “Fragile Five” countries show more significant responses.

Moreover, equity flows to these emerging markets increase following a positive US QE shock, although the effects are imprecisely estimated and more significant for the “Fragile Five” countries. We also find some evidence of a negative effect on trade flows on some of the “Fragile Five” countries, but little evidence suggesting a significant impact of the US QE shock on industrial production and consumer prices for any of the emerging economies. Thus overall, there is stronger evidence of spillover effects of US QE policy on financial variables compared to real macroeconomic variables and a stronger impact on the “Fragile Five” countries compared to other emerging market economies in our sample.

The rest of the paper is organized as follows. Section 2 describes the data, while section 3 describes the methodology for identifying the US QE shock and for estimating the spillover effects on the emerging market economies. In section 4, we describe the results, first for the US economy, and then for the emerging market economies. We conclude in section 5 by discussing our main results and topics for future research.

\section{Data}

We use US macroeconomic and financial data at the monthly frequency from June 2008 to June 2014 obtained from the FRED database and Core Logic.\(^7\) We employ the series of securities held outright by the Federal Reserve as a measure of unconventional monetary policy. It consists of the holdings of US Treasury securities, Federal agency debt securities, and

\(^6\)We choose these countries following classification of emerging economies by the IMF and Morgan Stanley. We exclude countries that suffered from major economic crises during our sample period or are in the Eurozone (and hence are more vulnerable to the European debt crisis) as well as some other countries which have followed some non-traditional exchange rate policy such as China and Russia.

\(^7\)All the data is from FRED except for the House Price Index data from Core Logic.
mortgage-backed securities by the Federal Reserve and thus is an important measure of the size of the asset side of the Federal Reserve balance sheet. In particular, these holdings are due to outright purchases by the Federal Reserve, which were a main component of unconventional monetary policy actions. Figure 1 plots securities held outright along with 10-year Treasury yields, S&P 500 index, and nominal (trade-weighted) effective exchange rate. The vertical lines represent the major dates of onset of Lehman crisis, several phases of quantitative easing by the Federal Reserve, and the taper talk. This figure suggests that after some lag, these interventions likely contributed to driving down long-term interest rates, led to a stock market boom and depreciation of the US dollars.

Figure 1: Selected US macro and financial data


We assess international spillover effects of the quantitative easing on the following important emerging market countries: Chile, Colombia, Brazil, India, Indonesia, Malaysia, Mexico, Peru, South Africa, South Korea, Taiwan, Thailand, and Turkey. We collect output, prices, USD exchange rate, stock market index, long term and short term interest rates data from

\[ \text{During normal times, this measure does not vary much as it just used to account for some secular changes in currency demand. Moreover, this measure is about the size of the asset side of the balance sheet and not its composition.} \]
Datastream and Bloomberg, trade flows data from Direction of Trade Statistics and capital flows data from EPFR. We first focus on a subset of these countries, Brazil, India, Indonesia, South Africa, and Turkey, as they reacted very strongly to the possibility of withdrawal of the QE program as mentioned by the Fed Chairman, Ben Bernanke, in May 2013. In popular media, these countries thus came to be known as the “Fragile Five” due to the potential vulnerability of their economies to US QE policy. We then next analyze whether these countries reacted any differently from the rest of the emerging market economies to the US QE shock.

![Figure 2: Long-term interest rates in selected emerging market economies](image)

Notes: See the notes in Figure 1.
Figure 3: Major stock market indices in selected emerging market economies

Notes: All indices are in thousands. Also see the notes in Figure 1.
Figure 4: Nominal exchange rates against US dollars in selected emerging market economies

Notes: Nominal exchange rates are the domestic currency price of a US dollar. Also see the notes in Figure 1.

Figure 5: The log of cumulative equity inflows in selected emerging market economies

Notes: See the notes in Figure 1.

Figures 2-5 show how long term yields, stock prices, exchange rates and capital flows of
the “Fragile Five” countries behaved during this time period. Generally, with the onset of quantitative easing in the US and the expectation of lower long-term US interest rates (Figure 1), this subset of emerging market countries experienced lower interest rates and higher stock prices (Figures 2 and 3), appreciated exchange rates (Figure 4) and capital inflows (Figure 5). In addition, on May 2013, the “taper scare” period, during which financial markets were surprised by the Federal Reserve’s intentions of slowing down its purchases of long-term assets and which turn lead to expectation of tighter policy and higher long-term interest rates in the U.S. (Figure 1), this subset of emerging market countries experienced higher interest rates and lower stock prices (Figures 2 and 3), depreciated exchange rates (Figure 4), and capital outflows (Figure 5). More generally, Figures 2-5 illustrate some of the international spillovers of quantitative easing policies adopted by the U.S. Federal Reserve.

3 Methodology

We first estimate a monthly VAR on the US data using Bayesian methods to identify US QE shocks. The baseline VAR for the US economy includes the index for industrial production as a measure of output, the private consumption expenditures (PCE) deflator as a measure of the price level, securities held outright on the balance sheet of the Federal Reserve as a measure of the monetary policy instrument, 10-year Treasury yields as a measure of long-term interest rates, and the S&P500 index as a measure of asset prices. The size of the Federal Reserve balance sheet as measured by the securities held outright is assumed to be the instrument of the QE program after the zero lower bound for nominal interest rates started binding in the US. We include the stock market price index, unlike much of the literature, in the US VAR as the outcomes and effects on the financial market were an important aspect of policy making during the QE period.

We impose non-recursive short-run restrictions on the US VAR to identify exogenous variations in the securities held outright, which are referred to as QE shocks, in an approach similar to that employed by, for example, Leeper, Sims, and Zha (1996) and Sims and Zha (2006a; 2006b) to identify US conventional monetary policy shocks. Specifically, consider a VAR model

\[ A_0 y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_l y_{t-l} + \varepsilon_t, \]

where \( y_t \) is an \( n \times 1 \) vector of endogenous variables and \( \varepsilon_t \sim N(0, I_n) \) with \( E(\varepsilon_t|y_{t-1}, y_{t-2}, \cdots) = 0. \) Table 1 describes identifying restrictions on \( A_0 \) where the columns correspond to the variables while the rows correspond to the sectors.

The first two sectors (“Prod1” and “Prod2”) in Table 1 are sectors related to the real

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9Gambacorta et al (2014) used a mixture of sign and zero restrictions in a VAR without long-term yields.
Table 1: Identifying restrictions on $A_0$

<table>
<thead>
<tr>
<th></th>
<th>Industrial production</th>
<th>PCE deflator</th>
<th>Securities held-outright</th>
<th>10-year Treasury yields</th>
<th>S&amp;P500 index</th>
</tr>
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<tbody>
<tr>
<td>Prod1</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Prod2</td>
<td>X</td>
<td>X</td>
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<td>F</td>
<td>X</td>
<td>X</td>
<td>$a_1$</td>
<td>$a_2$</td>
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<tr>
<td>MS</td>
<td></td>
<td></td>
<td>$a_3$</td>
<td>$a_4$</td>
<td></td>
</tr>
</tbody>
</table>

Notes: “X” indicates that the corresponding coefficient of $A_0$ is not restricted and blanks mean that the corresponding coefficient of $A_0$ is restricted to zero.

economy, determining relatively slow-moving variables like output and prices. The third equation (“I”) refers to the information sector and determines the fast-moving asset price variables which react contemporaneously to all the variables. In these three sectors, our identification assumptions follow Sims and Zha (2006b) directly.

The last two equations (“F” and “MS”) in Table 1 are respectively the long-run interest rate determination and policy equation. For the policy equation, we assume that the monetary policy instrument reacts contemporaneously only to the long-term interest rate. The assumption that the Federal Reserve does not react contemporaneously to industrial production and prices is the same as in Leeper, Sims, and Zha (1996) and Sims and Zha (2006a; 2006b). Here, we additionally posit no contemporaneous reaction of the policy instrument to the stock price index on the grounds that the Federal Reserve would not want to respond immediately to temporary fluctuations in stock prices. We thus postulate that the QE policy of the Federal Reserve is well approximated by a rule that determines the Federal Reserve’s purchase for securities as a linear function of the contemporaneous long-term yield and the lags of macroeconomic and financial variables. The long-run interest rate determination equation embodies restrictions similar to those in the traditional money demand equation in Sims and Zha (2006b) where the long-term interest rate adjusts contemporaneously to changes in output, prices, and asset purchases by the Federal Reserve.

In order to identify these two last equations separately, we follow Sims and Zha (2006b) and impose the following restrictions on the prior distribution of the coefficients known as the “Liquidity Prior.” In the interest rate determination equation (“F”), long-term yields tend to decrease as securities held outright increase (specifically, $\text{Corr}(a_1, a_2) = 0.8$), while in the policy equation (“MS”), securities held outright tend to increase as long-term yields increase (specifically, $\text{Corr}(a_3, a_4) = -0.8$). The latter implies a natural restriction that policy makers would purchase more securities in response to a rise in long-term interest rates. Note that here the restrictions are on the correlation coefficients in the prior distribution, and hence,
are weaker than the sign restrictions imposed on the impulse responses (e.g. those imposed by Gambacorta et al (2014)).

After identifying the QE shock from the estimated US VAR, we assess its dynamic effects on the emerging economies by feeding it into a system of equations for the emerging market economies. Specifically, for emerging market economy \(i\), we estimate a baseline four-variable Bayesian VAR with the US QE shock as an exogenous variable:

\[
z_{i,t} = B_{i,1}z_{i,t-1} + \cdots + B_{i,p}z_{i,t-p} + D_{i,0}z_{QE,t} + \cdots + D_{i,q}z_{QE,t-q} + u_{i,t},
\]

where \(z_{i,t}\) is an \(m \times 1\) vector of endogenous variables, \(z_{QE,t}\) is the US QE shock estimated in the US VAR and \(u_{i,t} \sim N(0, \Sigma_u)\) with \(E(u_{i,t}|z_{i,t-1}, z_{i,t-2}, \cdots) = 0\), and analyze the impulse response to an increase in the US QE shock. In our baseline specification, we include industrial production, CPI, 3-month interest rates and bilateral exchange rates against the US Dollar. Because of limitations on the number of data points, we first estimate this four-variable VAR and then add one additional variable at a time to assess the impact of the US QE shock on other important variables such as stock prices, long-term yields, equity flows, and trade flows. Note that here it is important to include the short-term interest rate in this VAR to control for endogenous response of monetary policy in these countries to the US QE shock.

This two-step estimation of the effect of the US QE shock on an emerging market economy is equivalent to estimating its effect in a VAR for both the US and the emerging market economy with a block exclusion restriction that the emerging market economy does not influence the US economy at all except for differences due to simulation of the posterior distribution. For ease of estimation, we prefer to identify and estimate the US QE shock in a VAR for the US economy only and then use the estimated QE shock in a separate VAR for emerging market economies.\(^{10}\)

The details of estimation are as follows. We include six lags of the variables in the US VAR, in a baseline specification and in a specification for robustness exercises, and use the data in the period from 2008:1 through 2008:6 as initial conditions. The US VAR is estimated using Bayesian methods with the Minnesota prior-type priors as in Sims and Zha (2006b) and we extract the QE shock as the posterior median of the identified QE shock.\(^{11}\) VAR models for emerging market economies include three lags for endogenous variables and three lags of the US QE shock. Note that the estimated US QE shock is available only from 2008:7. The sample period for the VARs for emerging market economies starts from 2008:8, but the first three observations (2008:8-2008:11) are used as lags in the VAR for emerging market economies.

\(^{10}\)We do not use a local projection method as it is difficult to estimate impulse responses precisely without some dynamic restrictions on them because of the relatively small size of our sample.

\(^{11}\)In particular, we use hyperparameters that control tightness of priors for \(A_0, A^+\), and the constant. Moreover, as is standard, we use a prior on “the sum of coefficients” favoring unit roots and cointegration.
4 Results

We now present our results on the identification and effects of the US QE shock based on the methodology described above. We start first with our estimates of the domestic effects of the US QE shock as well as our inference of the shock series. We then study the spillover effects of the US QE shock on emerging market economies. We finally present some robustness checks.

4.1 Domestic Effects of US QE Shock

From our estimated US VAR, we analyze the impulse responses to a positive shock in securities held outright, identified as an expansionary unconventional monetary policy shock.

Figure 6 shows the impulse responses for the baseline system. We find robust evidence in favor of a positive response in industrial production after a lag of 5 months and an immediate positive effect on consumer prices. Moreover, the financial variables respond significantly

\[ \text{Median responses} \]
\[ 68\% \text{ error bands} \]

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12 One technical difference is that \( A_0 \) is not estimated but the VCV matrix for the reduced-form shocks is estimated with the inverse-Wishart prior.
Figure 7: Impulse responses to the QE shock in the extended specification for the US VAR

Notes: The shock is one standard deviation (unit) shock in the monetary policy equation. Also, see the legend in Figure 6.

immediately—long term treasury yield falls and the stock price increases following an unanticipated expansion in the size of the balance sheet of the Federal Reserve.\footnote{We find the signs and the magnitudes of the impulse responses to be remarkably robust while including alternative measures of real activity (private consumption expenditures, nonfarm payroll), prices (CPI, CPI core), and other maturities of treasury securities. The details are provided later in the paper.} Our results on the effects of the US QE shock on US financial variables are consistent with the high-frequency based announcement effects literature. In addition, with our approach, here we can assess the effects on macroeconomic variables and find them to be significant. Like the identified VAR literature on conventional monetary policy, we find robust and significant effect on output. Somewhat differently from that literature, perhaps strikingly so, we also find strong effects on consumer prices.

We further assess the effects of a QE shock on financial market variables by extending the baseline VAR with inclusion of other variables. Figure 7 shows the impulse responses when we include the 20-year treasury yield in the baseline system. In terms of identification, we extend the restrictions in Table 1 by including the 20-year yield in the interest rate determination (“F”) sector. We find a robust decline also in the 20-year yield in response to an expansionary US QE shock.

We next consider a further extension of our baseline five variable VAR. We do so by adding
two important variables: a private sector yield and an additional asset price. For private sector yields, we consider both a corporate yield and a mortgage yield. The corporate yield measure, the effective yield of the BofA Merrill Lynch US Corporate 10-15 Year Index, include a subset of the BofA Merrill Lynch US Corporate Master Index tracking the performance of US dollar denominated investment grade rated corporate debt publicly issued in the US domestic market. The mortgage yield measure, the 30-year Conventional Mortgage Rate, is the contract interest rates on commitments for 30-year fixed-rate first mortgages. For the additional asset price, we consider both the nominal exchange rate and house price index. For the nominal exchange rate, we use the US nominal effective exchange rate while for house prices, we use the Core Logic House price index.

In terms of identification, we now include the private sector yield (one at a time) in the interest rate determination ("F") sector and the two additional asset prices (one at a time) in the information ("I") sector. Moreover, we impose that the Federal Reserve does not respond to the private sector yield or the additional asset price contemporaneously. The specific identifying restrictions in this expanded VAR are presented in Table 2. Like earlier, Table 2 describes identifying restrictions on $A_0$ where the columns correspond to the variables while the rows correspond to the sectors:

<table>
<thead>
<tr>
<th>Prod1</th>
<th>Prod2</th>
<th>I</th>
<th>I</th>
<th>F</th>
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Notes: “X” indicates that the corresponding coefficient of $A_0$ is not restricted and blanks mean that the corresponding coefficient of $A_0$ is restricted to zero.

Figure 8 shows the impulse responses when we extend the baseline VAR by including both a measure of corporate yield and the US nominal effective exchange rate. It is clear that the US QE shock both decreases the corporate yield as well as depreciates the US nominal effective exchange rate. Figure 9 shows the impulse responses when we extend the baseline VAR by including both a measure of mortgage yield and the US nominal effective exchange rate. It shows clearly that the US QE shock both decreases the mortgage yield as well as depreciates the US nominal effective exchange rate. Thus, these extended results are also consistent with

\[14\] Unlike for the bilateral exchange rates, for the effective exchange rate, a decrease constitutes a depreciation.
the financial market effects of QE policies identified in the announcement effect literature.

Figure 8: Impulse responses to the QE shock in the extended specification for the US VAR

Notes: The shock is one standard deviation (unit) shock in the monetary policy equation. Also, see the legend in Figure 6.

Figure 9: Impulse responses to the QE shock in the extended specification for the US VAR

Notes: The shock is one standard deviation (unit) shock in the monetary policy equation. Also, see the legend in Figure 6.
We next show our results when we include as private yield the Mortgage yield and as an asset price Housing prices. It is clear from Figure that the US QE shock both decreases the mortgage yield as well as increases the house price index. Again, these extended results are consistent with the financial market effects of QE policies identified in the announcement effect literature.

NEED TO ADD REFERENCE TO THE HOUSE PRICE FIGURE HERE

The estimated identified QE shock from the baseline VAR for the US is presented in Figure 10 along with the growth rate in securities held outright and the reduced form QE shock (the shock to securities held outright). Note that we have postulated that the unconventional monetary policy of the Federal Reserve is well approximated by a rule that determines the Federal Reserve’s demand for securities as a linear function of the contemporaneous long-term yield and the lags of macroeconomic and financial variables. The estimated QE shock presented in Figure 10 then can be understood as the unanticipated deviation of securities held outright from this prescription of policy, which is exogenous to the development of the US economy. The growth rate of securities held outright is a first-pass measure of QE by the Federal Reserve. However, it partly reflects the endogenous response of the Federal Reserve’s demand for securities to the state of the US economy and thus is not appropriate to estimate the causal effect of unconventional monetary policy. Indeed our identified QE shock series are
not perfectly matched with the growth rate of securities held outright though they co-move with it to some extent. They are not exactly aligned with important announcement dates of the QE program as well. We believe that our econometric methodology that is based on a system of equations for macroeconomic and financial data and identifying restrictions for structural shocks allows us to separate out the dynamic effects of QE apart from its immediate announcement effects. Finally, there is also a difference between the identified and the reduced form shock, illustrating the role played by our identification assumptions.

Figure 10: Identified US QE shocks and the growth rate of securities held outright by the Federal Reserve


Finally, we assess the importance of the identified US QE shock in explaining forecast error variance of the various variables at different horizons. As documented by the large literature on conventional monetary policy shock, the US QE shock explains a non-trivial, but not predominant, amount of variable in output and prices. For example, at the 6 and 12 month horizons, the QE shock explains at most 15% of the variation in output and prices and a similar fraction of the variation for long-term interest rates and stock prices.
Table 3: Variance Decomposition

<table>
<thead>
<tr>
<th>Impact</th>
<th>Industrial production</th>
<th>PCE deflator</th>
<th>Securities held-outright</th>
<th>10-year Treasury yields</th>
<th>S&amp;P500 index</th>
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<td>0.03</td>
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<tr>
<td></td>
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<td>[0.33, 0.78]</td>
<td>[0.1, 0.51]</td>
<td>[0.00, 0.06]</td>
</tr>
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<td>3 month</td>
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<td>0.03</td>
<td>0.51</td>
<td>0.17</td>
<td>0.06</td>
</tr>
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<td>[0.00, 0.01]</td>
<td>[0.00, 0.05]</td>
<td>[0.29, 0.74]</td>
<td>[0.02, 0.33]</td>
<td>[0.01, 0.12]</td>
</tr>
<tr>
<td>6 month</td>
<td>0.04</td>
<td>0.07</td>
<td>0.50</td>
<td>0.17</td>
<td>0.12</td>
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<tr>
<td></td>
<td>[0.00, 0.08]</td>
<td>[0.02, 0.13]</td>
<td>[0.28, 0.72]</td>
<td>[0.01, 0.33]</td>
<td>[0.02, 0.21]</td>
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<tr>
<td>12 month</td>
<td>0.15</td>
<td>0.15</td>
<td>0.38</td>
<td>0.18</td>
<td>0.18</td>
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<td></td>
<td>[0.04, 0.26]</td>
<td>[0.05, 0.26]</td>
<td>[0.19, 0.57]</td>
<td>[0.02, 0.36]</td>
<td>[0.04, 0.33]</td>
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Notes:

4.2 Spillover Effects of US QE Shock

We now assess the international spillover effects on emerging markets of the US QE shock identified and estimated above. We first start with the “Fragile Five” countries.

4.2.1 Fragile Five Countries

Figures 11-13 display the impulse responses of nominal exchange rates, long-term yields and major stock market indices for the “Fragile Five” countries and Figure 14 plots the impulse responses of equity flows for Brazil and Turkey to the estimated US QE shock, along with one standard deviation error bands.

Several results stand out. First, a monetary expansion through the QE program in the US leads to a depreciation of US dollar quite uniformly against the currencies of the emerging market economies. Figure 11 shows that currencies of Indonesia and Turkey went through a particularly robust and significant appreciation, while the median response is consistently negative for the rest of the countries. This result confirms anecdotal evidence on the behavior of exchange rates of these emerging market economies that has received significant attention in the media, in particular after the taper scare period. Second, we find that a positive QE shock in the US causes a decline of the long-term yields and a boom in the stock market in the emerging market economies. In Figure 12, long-term yields negatively respond to a positive US QE shock in the short-run for all the five countries. For Turkey, the significant impact of the US QE shock on long-term yields persists for almost two years. This decline in long term rates is consistent with international spillover of announcement effect literature, e.g. Neely (2013) and Glick and Leduc (2012). Evidence on the stock market indices is not as strong as that on the long-term yields. As Figure 13 shows, the stock market of India strongly and persistently booms after a US QE shock while the effect is marginally significant for the stock markets in Indonesia and Turkey. The stock market in Brazil responds negatively
Figure 11: Impulse responses of nominal exchange rates against the US dollar for selected emerging market economies

Notes: Exchange rates are the domestic currency price of a US dollar for each country. The responses are to a one-standard deviation (unit) increase in the US QE shock identified in the baseline VAR for the US. Also, see the legend in Figure 6.

for two periods. Such positive effects of the US QE shock on asset prices in the emerging markets suggest a possibility of capital inflows into the emerging market economies generated by investors in the US who are “reaching for yield.” This in fact is supported by a significantly positive equity inflows into Brazil in response to a US QE shock shown in Figure 14.\textsuperscript{15}

\textsuperscript{15}We analyzed equity flow data for Brazil and Turkey only for now, but plan to expand our dataset on capital inflows to include data for other emerging market countries.
Figure 12: Impulse responses of long-term yields for selected emerging market economies

Notes: For the information on the long-term yields, see the main text. Also, see the notes in Figure 11.

Figure 13: Impulse responses of major stock market indices for selected emerging market economies

Notes: For the information on the stock market indices, see the main text. Also, see the note in Figure 11.
Figure 14: Impulse responses of cumulative equity flows for selected emerging market economies

Notes: For the information on cumulative equity flows, see the main text. Also, see the notes in Figure 11.
We now study the real implications of the QE shock. This is a major advantage of using a monthly VAR methodology as we can go beyond estimating just the effects on the financial variables. Figures 15, 16, and 17 show the impulse responses of industrial production, CPI, and the short-term (3 month) interest rate respectively for these emerging market countries. For output and consumer prices, we do not find significant effects. For the short-term interest rate, while the effects are not precisely estimated for all the countries, consistent with our results above for the long-term yields, they decline. Finally, in light of the appreciation of the currencies that we showed above, we assess the implications on net exports for these countries. Figure 18 shows that indeed a significant decline in net exports occurred in India and Indonesia following an expansionary QE shock. For other countries however, the effects are not precisely estimated.

Figure 15: Impulse responses of industrial production for selected emerging market economies

Notes: See the notes in Figure 11.

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16The main purpose of including the short-term interest rate in this VAR is to control for endogenous response of monetary policy in these countries to the US QE shock.
Figure 16: Impulse responses of CPI for selected emerging market economies

Notes: See the notes in Figure 11.

Figure 17: Impulse responses of 3-month interest rates for selected emerging market economies

Notes: See the notes in Figure 11.
Figure 18: Impulse responses of net exports to the US for selected emerging market economies

Notes: Net exports are in terms of US dollars and normalized by monthly GDP of each country. Also, see the notes in Figure 11.
4.2.2 Other Emerging Markets

We now study the spillovers to eight additional emerging market economies: Chile, Colombia, Malaysia, Mexico, Peru, South Korea, Taiwan, and Thailand. Like with the “Fragile Five” countries, we first start with financial variables. Figure 19 shows that exchange rate depreciation as a result of an expansionary US QE shock was not limited only to the “Fragile Five” countries as all countries’ other than Chile’s currency appreciate in a statistically significant manner against the US dollar. With long-term yields, there is also evidence of their reduction, as shown in Figure 20, but the effect is less strong than for the “Fragile Five” countries. The most significant response is in the long-term yields of Thailand and South Korea. Similarly, Figure 21 shows some evidence for a stock market boom in this set of emerging market economies as well, but the effects are most often not statistically significant. Finally, as shown in Figure , there is evidence for equity inflows in these countries following a positive US QE shock, but the effects are very imprecisely estimated and only statistically significant for Taiwan. Overall, these results suggest that qualitatively, the financial spillovers of the US QE shock are similar across all emerging markets, but the effects are somewhat more pronounced for the “Fragile Five” countries.

REFERENCE FIGURE FOR RESULTS ABOUT EQUITY FLOWS

Figure 19: Impulse responses of nominal exchange rates against the US dollar for other selected emerging market economies

Notes: See the notes in Figure 11.

NEED TO ADD THE EQUITY FLOWS FOR THESE COUNTRIES HERE
Figure 20: Impulse responses of long-term yields for other selected emerging market economies

Notes: See the notes in Figure 11.

We next assess the real implications of these financial spillovers. Like before, we now present the impulse responses of output, CPI, and net exports while including the response of the short-term interest rate as well for completeness.\textsuperscript{17} Except for a few instances, overall, Figures 22-25 show no evidence of statistically significant real effects of the US QE shock. In some instances for net exports, it in fact responds positively.

\textsuperscript{17}For these countries, we do not yet have access to capital flows data from EPFR.
Figure 21: Impulse responses of major stock market indices for other selected emerging market economies

Notes: See the notes in Figure 11.
Figure 22: Impulse responses of industrial production for other selected emerging market economies

Notes: See the notes in Figure 11.

Figure 23: Impulse responses of CPI for other selected emerging market economies

Notes: See the notes in Figure 11.
Figure 24: Impulse responses of 3-month interest rates for other selected emerging market economies

Notes: See the notes in Figure 11.

Figure 25: Impulse responses of net exports to the US for other selected emerging market economies

Notes: Net exports are in terms of US dollars and normalized by monthly GDP of each country. Also, see the notes in Figure 11.
4.2.3 Comparison Across Two Groups

We now compare the results for the two groups of emerging market economies that we considered above. To do so, for each group, across the countries, we compute the median of the effects at each point time. This exercise is useful both to get an overall picture for the two sets of countries as well as to compare them to each other. The results are shown in Figure. As is clear, for both sets of countries, there is evidence for exchange rate appreciation, stock market boom, reduction in long-term interest rates, as well as an increase in capital flows. Moreover, consistent with visual evidence from country-specific VARs above, the Fragile Five countries respond more strongly compare to the rest of the emerging market economies in our sample.

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RESULTS

4.3 Robustness and Extensions

We have used non-recursive restrictions on the $A_0$ matrix for identification of the US QE shock. Another widely used identifying restrictions in the empirical conventional monetary

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18 We have not computed error bands around these median estimates so far. We plan to make this exercise rigorous by estimating a panel VAR.
policy literature is to use recursive restriction on the $A_0$ matrix. A natural question is whether the recursive identification scheme would also work well for an unconventional monetary policy case. To investigate this, we use the set of restrictions illustrated below in Table 3. To make the restrictions as close to our baseline identification strategy, we could use two possible ordering of variables. In both, it is natural to have Industrial production first, PCE deflator second, and S&P 500 Index last. We then experiment with having Securities held outright ordered third or fourth. In the former, it would imply that the Federal Reserve would not respond to the long-term interest rate contemporaneously, while in the latter, it would. Note that as is well-known, one important difference between the recursive and non-recursive identification schemes is whether current Industrial production and PCE deflator are in the information set of the Federal Reserve or not. In addition, here, it also means that the liquidity prior restrictions that we imposed before on both the monetary policy equation as well as the financial markets equation can no longer be applied as $A_0$ is lower-diagonal. Thus, we can only use one set of liquidity priors.

Table 4: Identifying recursive restrictions on $A_0$

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Notes: "X" indicates that the corresponding coefficient of $A_0$ is not restricted and blanks mean that the corresponding coefficient of $A_0$ is restricted to zero. Two identification schemes based on ordering as described in the text are used in the paper. In both, Industrial production is first, PCE deflator second, and S&P 500 Index last. The differences between the two is whether Securities held outright is ordered third or fourth.

Figures show that the recursive identification scheme has issues with separating shifts in monetary policy from shifts in the financial market. Thus, when securities held outright increase exogenously, we see that long-term interest rates increase, which is in contradiction to our baseline results. Based on these results, we thus conclude that the combination of non-recursive restrictions on the $A_0$ matrix and liquidity priors are essential in our baseline exercise to identify a US QE shock.

ADD THE REFERENCE TO THE TWO FIGURES HERE FOR THE RECURSIVE CASE.

We have also undertaken other extensive robustness checks on our baseline VAR estimation on US data. Details of some of these exercises are in the appendix, where we show that our results are largely robust to considering alternative Treasury yields, output measures,
consumer price measures, our house price measures. In particular, while statistical significance is an issue for some cases, an expansionary QE shock robustly decreases Treasury yields and increases output and prices.

5 Conclusion

In this paper we estimate the spillover effects of US Quantitative Easing (QE) on emerging market economies. Using a VAR with non-recursive identification method on monthly US macroeconomic and financial data, we first estimate a US QE shock and infer its effects on US variables. We find that an unanticipated expansionary US QE shock led to an increase in output and consumer prices in the US. These results are remarkably robust and strong. In addition, we find that the US QE shock also drove down long-term treasury yields while increasing stock prices. In an extension, we also provide evidence in support of reductions in corporate and mortgage yields as well as a depreciation of the US exchange rate and an increase in housing prices. Thus, the QE shock had a significant effect on both financial and macroeconomic variables in the US.

We then use this identified US QE shock to infer the spillover effects on emerging market economies with a focus first on the “Fragile Five” countries: Brazil, India, Indonesia, Turkey, and South Africa. We find that an expansionary US QE shock leads to an exchange rate appreciation, a reduction in long-term bond yields, and a stock market boom for these emerging market countries. These effects, while smaller, are also present for other emerging market economies. Other than positive effects on equity flows and a reduction in net exports for the “Fragile Five” countries, we do not find consistent and significant effects of the US QE shock on other macroeconomic variables such as output and prices of any emerging market countries.

In future work, we plan to conduct counterfactual experiments as well as use a panel VAR methodology to further assess the spillover effects of the US QE shock. Our empirical results should be helpful in establishing a set of stylized facts that can guide open economy models of unconventional monetary policy transmission mechanism. Thus, one can use these results to extend standard open economy models such as Corsetti and Pesenti (2005) and Clarida, Gali, and Gertler (2002). While doing so, various mechanisms proposed in the closed-economy literature for why quantitative easing policies have macroeconomic effects can be extended to the open economy. Some examples are effects of quantitative easing through credit intermediation (Gertler and Karadi (2011)), provision of scarce collateral (Williamson (2012)), or signalling of future lower interest rates (Bhattarai, Eggertsson, and Gafarov (2015)).
References


Here, we show results when we undertake robustness checks by considering alternate Treasury yields and output and price measures in our baseline five variable US VAR.