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 panel VAR for emerging market economies to infer the international spillover effects on these countries. We find that an expansionary US QE shock has significant effects on financial variables in emerging market economies. It leads to an exchange rate appreciation, a reduction in long-term bond yields, a stock market boom, and an increase in capital flows to these countries. These effects on financial variables are stronger for the “Fragile Five” countries compared to other emerging market economies. 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; Panel VAR

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 focussing 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 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 important 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

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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 Decemeber 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.
regarding the spillover effects on financial markets of emerging economies, both during the ongoing phase of the quantitative easing program as well as its tapering and eventual end. 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 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 (which consists of all outright asset purchases) as our baseline measure. 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.

Next, 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. Given the identified QE shock from the estimated baseline US VAR, we estimate a Bayesian panel VAR involving macroeconomic and financial variables for the emerging markets, in which the US QE shock is treated as an exogenous variable. On average, there are statistically and economically significant effects on exchange rate, long-term bond yields, and stock prices of these emerging market economies, but no effect on output

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

\[^5\text{In this sense our approach is similar to that of Gambacorta et al (2014) who focused on domestic implications, on some macroeconomic variables, of quantitative easing by several countries using a central bank balance sheet variable as an instrument of policy. Our identification method as well as the empirical focus is however, different as we detail later.}\]

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

\[^7\text{Since dynamic heterogeneity is likely to be important, we do not completely pool the data. Instead, we use a random coefficients panel VAR approach that partially pools the cross-sectional information. We describe our method in detail later in the paper.}\]
and consumer prices. In particular, an expansionary US QE shock appreciates the currency, decreases long-term bond yields, and increases stock prices of these countries. In addition, we find that equity flows increase to this countries following an expansionary US QE shock.\textsuperscript{8} Net exports however do not respond significantly.

Moreover, we show that the so called “Fragile Five” countries, Brazil, India, Indonesia, Turkey, and South Africa, respond more strongly and significantly differently from the rest of emerging market economies. This holds for all financial variables that we consider, including equity flows. Real macroeconomic variables however do not respond in a statistically significant manner even for the “Fragile Five” countries. 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.\textsuperscript{9} 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 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.\textsuperscript{10} 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 dollar.

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 Datastream and Bloomberg, trade flows data from Direction of Trade Statistics and capital flows data from EPFR. Here, for

\textsuperscript{8}These capital flow data are obtained from a large micro-data set that tracks global fund level data to emerging market economies. We describe our data in detail later.

\textsuperscript{9}All the data is from FRED except for the House Price Index data from Core Logic.

\textsuperscript{10}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.
Figure 1: Selected US macro and financial data


motivation purposes only, we 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.

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 in 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.
Figure 2: Long-term interest rates in selected emerging market economies

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.
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.\(^\text{11}\) 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.

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>
</thead>
<tbody>
<tr>
<td>Prod1</td>
<td>X</td>
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<tr>
<td>Prod2</td>
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<tr>
<td>MS</td>
<td>(a_3)</td>
<td>(a_4)</td>
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</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.

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

\(^{11}\)Gambacorta et al (2014) used a mixture of sign and zero restrictions in a VAR without long-term yields.
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. In particular, we take a random-coefficients panel VAR approach to account for dynamic heterogeneity across countries. The panel VAR set-up is given by, for each country \( i \),

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

with \( u_{i,t} \sim N(0, \Sigma_i) \) and \( E(u_{i,t}|z_{i,t-1}, z_{i,t-2}, \cdots) = 0 \), where,

\[
B_{i,j} = \tilde{B}_j + v_{B_{i,j}};
\]
\[
D_{i,k} = \tilde{D}_k + v_{D_{i,k}};
\]
\[
C_i = \tilde{C} + v_{C_i},
\]

with \( v_{B_{i,j}} \sim N(0, \Omega_{B_{i,j}}) \), \( v_{D_{i,k}} \sim N(0, \Omega_{D_{i,k}}) \), and \( v_{C_i} \sim N(0, \Omega_{C_i}) \). Here, \( z_{i,t} \) is an \( m \times 1 \) vector of endogenous variables, \( e_{Q,E,t} \) is the US QE shock estimated in the US VAR, and \( x_t \) is a vector of exogenous variables including a constant term and dummy variables that are common across countries.

In our baseline specification, for variables in \( z_{i,t} \), we include industrial production, CPI, 3-month interest rates, and bilateral exchange rates against the US Dollar. To take into account the fact that
many of the emerging market countries in our sample are commodity exporters, a measure of world
demand for commodities and a price index of commodities are included in $x_t$. Dummy variables
to control for the effect of the European debt crisis (May 2010 and February and August 2011) are
also included in $x_t$.

Because of limitations on the number of data points, we first estimate this five-variable panel
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 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. We also show results when we include
only financial variables in the panel VAR.

This two-step estimation of the effect of the US QE shock on emerging market economies is
equivalent to estimating its effect in a VAR for both the US and the emerging market economies
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 panel VAR for emerging market economies.

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. Panel VAR model for emerging market
economies includes five lags for endogenous variables and five lags of the US QE shock. Note that
the estimated US QE shock is available only from 2008:7. The sample period for the panel VAR 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. Because of the concern on the degrees of
freedom of the VARs for emerging market economies with the estimated US QE shock included, we
include only five lags of endogenous variables. A Minnesota type prior similar to that for the US
VAR is also employed for the emerging market panel VAR.

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.

12The measure of world demand for commodities is the index of global real economic activity in industrial commodity
markets estimated by Lutz Kilian. The commodity price index is all commodity price index provided by IMF.
13In 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.
14One 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.
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 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. 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 measures of real activity (private consumption expenditures, non farm payroll), prices (CPI, CPI core), and other maturities of treasury securities. The details are provided later in the paper.

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15 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, non farm payroll), prices (CPI, CPI core), and other maturities of treasury securities. The details are provided later in the paper.
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:

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

\[16\] Unlike for the bilateral exchange rates, for the effective exchange rate, a decrease constitutes a depreciation.
### Table 2: Identifying restrictions on $A_0$

<table>
<thead>
<tr>
<th></th>
<th>Industrial production</th>
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<th>Private yields</th>
<th>S&amp;P500 index</th>
<th>Additional Asset Price</th>
</tr>
</thead>
<tbody>
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<td>Prod1</td>
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<td>Prod2</td>
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<td>$a_3$ $a_4$</td>
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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.

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 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](image)

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 house prices. It is clear from Figure 10 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.

The estimated identified QE shock from the baseline VAR for the US is presented in Figure 11 along with the growth rate in securities held outright and the reduced form QE shock (the shock to
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.

Figure 10: 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.

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 11 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 11: Identified US QE shocks, reduced form shocks to securities held outright, and the growth rate of securities held outright by the Federal Reserve

Notes: See the notes in Figure 1.

Finally, we assess the importance of the identified US QE shock in explaining forecast error variance of the various variables at different horizons. This variance decomposition result is presented in Table 3. As documented by the large literature on conventional monetary policy shock, the US QE shock explains a non-trivial, but not predominant, amount of variation 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>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.55</td>
<td>0.31</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>[0.00, 0.00]</td>
<td>[0.00, 0.00]</td>
<td>[0.33, 0.78]</td>
<td>[0.1, 0.51]</td>
<td>[0.00, 0.06]</td>
<td></td>
</tr>
<tr>
<td>3 month</td>
<td>0.01</td>
<td>0.03</td>
<td>0.51</td>
<td>0.17</td>
<td>0.06</td>
</tr>
<tr>
<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>
<td></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>
</tr>
<tr>
<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>
<td></td>
</tr>
<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>
</tr>
<tr>
<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>
<td></td>
</tr>
</tbody>
</table>

Notes: The table shows the contribution of the QE shock for the fluctuations (forecast error variance) of each variable at a given horizon. We report the mean with the 16% and 84% quantiles in square brackets.

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 estimate a panel VAR of emerging market economies to obtain some pooled estimates that incorporate the cross-sectional information. Since dynamic heterogeneity is likely to be prevalent, we use a random coefficient approach that partially pools the cross-sectional information. The inference is again Bayesian with priors similar to that of the US VAR.

4.2.1 Overall effects

In particular, we are first interested in overall dynamic effects of the US QE shock as given by the “average” effects computed using $\bar{B}_j$ and $\bar{D}_k$. We show this in Figure 12, where we present impulse response functions that depict median responses and one 68% error bands. As we mentioned before, we first estimate a baseline VAR with output, prices, short term interest rate, exchange rate, and stock prices and then add one additional variable at a time. The Figure shows clearly that on average, the currencies of these emerging markets appreciated significantly while long-term bond yields decreased (and consistently, the Emerging Market Bond Index (EMBI) increased). 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. The decline in long term rates is consistent with international spillover of announcement effect literature, e.g. Neely (2013) and Glick and Leduc (2012). The effect on stock prices is also positive and is accompanied by an increase in equity flows to these countries. This is consistent with U.S. investors “reaching for yield” in emerging financial markets. Moreover, there are no statistically significant
effects on real variables such as output and consumer prices and net exports.\textsuperscript{17}

Figure 12: Impulse responses of the panel VAR on emerging market economies

Notes: Exchange rates are the domestic currency price of a US dollar for each country. For description of other variables, see the main text. 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.

To highlight the strong effect on financial variables of these countries, and to possibly mitigate some concerns of small sample bias, we also estimate a panel VAR with only four important financial variables. The results in Figure 13 show clearly that a US QE shock appreciated these counties’ currencies, decreased their long-term interest rates, increased their stock prices, and increased equity inflows to these countries.

4.2.2 Fragile Five vs. Others

Next we estimate a separate panel VAR for the Fragile Five countries and the other emerging market countries to compare the average effects between these two groups. The results in Figures 14 and 15 show clearly that the effects on financial variables such as exchange rate, long-term interest rates (and the EMBI), stock prices, and equity flows are stronger for the Fragile Five countries compared to the rest of emerging market countries. For real variables, there are no significant differences as while net exports does decrease for the Fragile Five countries, it is not statistically significant.

\textsuperscript{17}For conventional US monetary policy shock, Mackowiak (2007) also finds effects on exchange rate and interest rates of emerging market economies. Mackowiak (2007) find significant effects for output and prices as well, which is not the case for our unconventional US monetary policy shock.
Figure 13: Impulse responses of the panel VAR on emerging market economies with only financial variables

Notes: See the notes in Figure 12.

4.3 Robustness and Extensions

We now describe a series of robustness exercises and extensions to the baseline specifications that we have implemented.

4.3.1 Other activity and price measures

Our baseline measure for output in the US VAR was Industrial Production, which is a core measure often used in monthly VAR studies. We now conduct two robustness exercises with respect to the economic activity measure. First, we use interpolated monthly real GDP.\footnote{We use the Chow-Lin procedure for interpolation.} The results are presented in Figure 16. Second, to incorporate some information from labor markets, we use the coincident activity index produced by the Federal Reserve Bank of Philadelphia, which in addition to Industrial Production also uses data on unemployment and non-farm payroll, among others. The results are presented in Figure 17. It is clear that our inference on the effects of the QE shock on US macroeconomic and financial variables does not change.

Next, we use an alternate measure of consumer prices compared to the baseline. Our results so far use the PCE deflator as a measure of goods prices. We now use the CPI. The results are presented in Figure 17. Again, it is clear that our inference on the effects of the QE shock on US macroeconomic and financial variables does not change.

We have also undertaken other extensive robustness checks on our baseline VAR estimation on
Figure 14: Impulse responses of the panel VAR on emerging market economies: Fragile Five

Notes: See the notes in Figure 12.

US data. Details of some of these exercises are available on request and we find that our results are largely robust to considering alternative Treasury yields, consumer price measures, or 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.

4.3.2 Recursive identification

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 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 4. 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-triangular. Thus, we can only use one set of liquidity priors.
Figure 15: Impulse responses of the panel VAR on emerging market economies: Others

Notes: See the notes in Figure 12.

Figure 16: Impulse responses to the QE shock for the US VAR with GDP

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

Figures 19 and 20 show that the recursive identification scheme has issues with separating shifts
Figure 17: Impulse responses to the QE shock for the US VAR with Coincident Index

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

Table 4: Identifying recursive restrictions on $A_0$

<table>
<thead>
<tr>
<th>Industrial Production</th>
<th>PCE deflator</th>
<th>Securities (10-year yields)</th>
<th>10-year yields (Securities)</th>
<th>S&amp;P500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Production</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PCE deflator</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Securities (10-year yields)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>10-year yields (Securities)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>S&amp;P500</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</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. Each row corresponds to an equation, and thus the first column indicates a shock to each variable. 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.

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.
4.4 Discussion

We now assess what might be underlying fundamental reasons that led to the Fragile five countries to be more vulnerable and respond more strongly to the US QE shock. To provide such a narrative, we look at some key data from the pre-QE period, in particular from 2000-2007, for these two groups of countries. Our objective here is to present a picture of the “ex-ante” positions of these countries.

In Table 5, we present the average growth rates of the nominal exchange rate and stock prices as well as long-term interest rates from 2000-2007. It is clear that during this period, the fragile five countries had a more appreciating currency and stock market as well as higher long-term interest rates. Thus, it seems natural that as the Federal Reserve embarked on QE, these countries saw more stronger capital inflows as they were more attractive to investors.

<table>
<thead>
<tr>
<th></th>
<th>Fragile Five Countries</th>
<th>Rest of Emerging Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Exchange Rate</td>
<td>-0.37</td>
<td>-0.21</td>
</tr>
<tr>
<td>Long-term Interest Rates</td>
<td>15.02</td>
<td>4.96</td>
</tr>
<tr>
<td>Stock Prices</td>
<td>2.15</td>
<td>1.73</td>
</tr>
</tbody>
</table>

Notes: The monthly datasource is the same as in the panel VAR analysis. We present monthly growth rates for exchange rate and stock prices and averages for long-term interest rates (in %).

Next, in Table 6, we present 2000-2007 averages of some key external and fiscal “imbalance”...
Figure 19: Impulse responses for the US economy with a recursive identification

Notes: The shock is one standard deviation (unit) shock in the monetary policy equation.

variables. The objective here is to assess if these imbalances were more pronounced in the fragile five countries, which would then help provide an explanation for why they were more vulnerable to an external shock such as the US QE shock. Indeed, Table 6 shows clearly that the fragile five countries had a greater level of current account deficits and fiscal deficits, as well as a higher level of government debt.

Table 6: Averages of key imbalance variables from 2000-2007

<table>
<thead>
<tr>
<th></th>
<th>Fragile Five Countries</th>
<th>Rest of Emerging Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Account</td>
<td>-0.57</td>
<td>2.58</td>
</tr>
<tr>
<td>Fiscal Balance</td>
<td>-3.66</td>
<td>-1.05</td>
</tr>
<tr>
<td>Structural Fiscal Balance</td>
<td>-3.53</td>
<td>-1.35</td>
</tr>
<tr>
<td>Government Debt</td>
<td>59.7</td>
<td>34.5</td>
</tr>
</tbody>
</table>

Notes: The datasource is WEO. We take averages of annual data. Current account, fiscal balance, and government debt are presented as ratios of GDP while structural fiscal balance is presented as ratio of potential GDP (in %). Government debt is gross government debt. Net government debt is not available for all countries but the averages for them follow a similar pattern as gross government debt.
Figure 20: Impulse responses for the US economy with a recursive identification

Notes: The shock is one standard deviation (unit) shock in the monetary policy equation.

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 in a panel VAR framework. 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 are bigger for the “Fragile Five” countries, but are also present for other emerging market economies. We also find significant positive effect on equity flows to these countries following a positive US QE shock. We however, 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 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)). Finally, for comparison, we will identify a US monetary shock during the conventional time period with non-recursive restrictions and assess the effects of the shock on these emerging market countries. This will help us relate our results to other papers such as Mackowiak (2007).
References


