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JEL Classification

C31, E44, E52, E58, F32, F41, F42

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"*Among the advanced economies, the mutual benefits of monetary easing are clear. The case of emerging market economies is more complicated ...Because many emerging market economies have financial sectors that are small or less developed by global standards but open to foreign investors, they may perceive themselves to be vulnerable to asset bubbles and financial imbalances caused by heavy and volatile capital inflows, including those arising from low interest rates in the advanced economies.*" (Federal Reserve Chairman Ben Bernanke in a speech in 2013)

"*There is little doubt that the aggressive actions the Federal Reserve took to mitigate the effects of the global financial crisis significantly affected asset prices at home and abroad as well as international capital flows ...An easing of monetary policy in the United States benefits foreign economies from both stronger U.S. activity and improved global financial conditions. It also has an offsetting contractionary effect on foreign economies because their currencies appreciate against the dollar.*" (Federal Reserve Vice Chairman Stanley Fischer in a speech in 2014)

1 Introduction

As a countercyclical response to the onset of the Great Recession in 2007, the US Federal Reserve drastically cut the federal funds rate, the conventional monetary policy instrument. Once the federal funds rate effectively hit the zero lower bound (ZLB) at the end of 2008, the Federal Reserve engaged in unconventional monetary policies to provide further stimulus. In particular, through a policy called the large-scale asset purchase (LSAP) program, it purchased longer-term government/agency bonds and mortgage backed securities. This policy, often referred to as quantitative easing (QE), greatly affected the size and composition of the Federal Reserve balance sheet. QE's main goal was to lower long-term interest rates and thereby, spur economic activity, even as the short-term interest rate was stuck at the ZLB.[1]

In this paper, we evaluate the international spillover effects of the QE program of the Federal Reserve by assessing its impact on emerging market economies. When the Federal Reserve started its QE policy in 2008, emerging market economies received massive capital inflows and their currencies appreciated. These developments can potentially have significant financial and macroeconomic effects. Our focus is also partly motivated by how popular media and policy-making circles were rife with concerns about the spillover effects on emerging economies, not only during the initial phase of the QE program, but also during its later phases and eventual end.[2]

[1] We will use LSAP and QE interchangeably in the paper.

[2] Examples of such attention in policy are the following quotes from speeches by policy makers in Brazil and India:

"*This (economic) crisis started in the developed world. It will not be overcome simply through measures of austerity, fiscal consolidations and depreciation of the labour force; let alone through quantitative easing policies that have triggered what can only be described as a monetary tsunami, have led to a currency war and have introduced new and perverse forms of protectionism in the world.*" (Brazilian President Dilma Rousseff in a speech in 2012)

"*The question is are we now moving into the territory in trying to produce growth out of nowhere we are in fact shifting growth from each other, rather than creating growth. Of course, there is past history of this during the Great Depression when we got into competitive devaluation ...We have to become more aware of the spill-over effects of our actions and the rules of the game that we have — of what is allowed and what is not allowed — needs to be revisited.*" (Governor of Reserve Bank of India Raghuram Rajan in a speech in 2015)

Our empirical strategy is to first identify the US QE shock in a structural vector autoregression (VAR), estimated on monthly US macroeconomic and financial data, and then assess its international implications in a panel VAR for the emerging market economies, estimated on their monthly macroeconomic and financial data. This allows us to document three features of the US QE policy. First, we estimate the effects of QE policies on the US economy, both on macroeconomic and financial variables, in a manner that is a close parallel to the approach in the conventional monetary policy VAR literature. Second, the panel VAR model for the emerging market economies that treats the US QE shock as an exogenous shock allows us to estimate macroeconomic and financial spillover effects of the US QE policy. Third, our panel VAR approach also allows us to assess important heterogeneity in responses across different subgroups of the emerging market countries.

We use the securities held outright on the balance sheet of the Federal Reserve, which consists of all outright asset purchases by the Federal Reserve, as our baseline measure for the QE/LSAP policy instrument. Then, using (non-recursive) restrictions on the short-run dynamics of the endogenous variables in the monthly US VAR, we isolate unanticipated exogenous changes in the QE policy instrument from endogenous adjustments of the same variable to the state of the economy. The idea is analogous to the one in the structural VAR literature that identifies a conventional monetary policy shock from a monetary policy rule, in particular the identification approach of Sims and Zha (2006 a,b). Like that literature, we refer to the exogenous changes in QE policy as the US QE shock.

In our baseline specification for the US VAR, we identify a strong impact of an unanticipated increase in asset purchases by the Federal Reserve on both output and consumer prices as well as robust evidence of a reduction in long-term Treasury yields and an increase in stock prices. Our result is robust to different choices of the measure for output and consumer prices. The magnitude of the effects of the QE shock is economically large. A one-standard deviation shock to QE amounts to about a 2% rise in the securities held outright by the Federal Reserve, which is an increase of about 40 billion dollars on average in our sample. A shock of this size decreases 10-year Treasury yields by around 10 bp on impact and increases stock prices by around 1% after a delay of 8 months. In addition, after some lag, we find a peak effect after around 10 months of 0.4% on output and 0.1% on consumer prices. While estimating extended specifications to the US VAR, we also find evidence of a reduction in corporate and mortgage yields, an improvement in labor market conditions, a depreciation of the US dollar, an increase in house prices, and a rise in long-term inflation expectations in the US.

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.[3] Given the identified QE shock from the estimated baseline US VAR, we estimate a monthly panel VAR involving macroeconomic and financial variables for the emerging markets where the US QE shock is included as an exogenous variable.[4] In an alternative specification, to connect more directly to the literature that focusses on

[3] 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 such as China and Russia that are known to manage their exchange rates.

[4] Since dynamic heterogeneity is likely to be important, we do not completely pool the data. Instead, we use a

financial markets effects and to mitigate some small sample concerns, we also estimate a financial panel VAR that includes only financial variables of the emerging market countries.

There are statistically and economically significant (average) effects on exchange rates, long-term bond yields, and stock prices of these emerging market economies. In particular, an expansionary US QE shock appreciates the local currency against the US dollar, decreases long-term bond yields, and increases stock prices of these countries. The impact effects on the nominal exchange rate is around 25 bp, on stock prices around 100 bp, and on long-term bond yields around 3 bp. For the nominal exchange rate and stock prices, the peak effects are around three times as large as the initial effects and occur 5 months after impact. In addition, we find that more capital flows into the financial markets of these countries following an expansionary US QE shock.[5] For instance, at its peak, capital inflows increase around 2%. This is a large effect. Using the average size of the capital flows in our data, this constitutes an average effect of 3.9 billion dollars on the aggregate and 300 million dollars per country. These effects on the financial variables are qualitatively and, for almost all the variables, quantitatively similar when we estimate the financial panel VAR. In this alternative specification, the effects on long-term bond yields are substantially stronger, with an impact response of 4 bp but a peak response two times as large 5 months after impact.[6]

With respect to the macroeconomic variables, we find no significant and robust effects on output and consumer prices of emerging markets. These results are not necessarily surprising as capital inflows and exchange rate appreciations can have opposite effects on production, as also emphasized recently by Blanchard et al (2015). Net exports also do not respond significantly on impact but, after several periods, respond positively. Given the exchange rate appreciation, this might be surprising, but other mechanisms, such as improved US financial conditions and an increase in US demand due to income effects, might drive net exports in the opposite direction, thereby canceling the negative effect of the exchange rate.[7]

Next, we investigate if there are meaningful differences in responses across some subgroups of the emerging market countries. Motivated by the attention that Brazil, India, Indonesia, Turkey, and South Africa, which came to be known as the "Fragile Five," received in the media due to the potential vulnerability of their economies to the US QE policy, we consider one group composed of these countries and another of the remaining eight countries.[8] We indeed find that these Fragile

random coefficients panel VAR approach that partially pools the cross-sectional information. We also allow shocks across the countries to be correlated. The method is similar to the one in Canova (2007) and Canova and Ciccarelli (2013) and we describe it in detail later in the paper.

[5] 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.

[6] These effects are thus consistent with the statements by Ben Bernanke and Stanley Fischer above.

[7] As argued for example, by Stanley Fischer in the quote above. Consider also the argument by Ben Bernanke from the same speech as above:

> *"Moreover, even if the expansionary policies of the advanced economies were to lead to significant currency appreciation in emerging markets, the resulting drag on their competitiveness would have to be balanced against the positive effects of stronger advanced-economy demand. Which of these two effects would be greater is an empirical matter."*

[8] As we discuss later in the paper, we also consider an alternative grouping of countries, in particular one that adds Mexico to the Fragile Five group.

Five countries respond more strongly and differently from the rest of emerging market economies. This holds for all the financial variables that we consider, including capital flows. For example, the peak response of exchange rates and long-term bond yields is around four times larger for the Fragile Five countries and capital flows respond significantly only for the Fragile Five countries. Output and consumer prices however do not respond in a statistically significant manner, even for the Fragile Five countries. Lastly, for net exports, the response is positive only for the Fragile Five group. In a discussion of these heterogeneous effects across country groups, we document that the higher vulnerability of the Fragile Five countries is correlated with some important ex-ante conditions and imbalances prior to the crisis. In particular, prior to the crisis, these countries had a larger appreciation of exchange rates, a faster rise of stock prices, and higher interest rate as well as larger macroeconomic imbalances, measured by current account, fiscal deficit, and debt to GDP ratio.

Thus, overall, our estimates from the panel VAR estimated on emerging markets suggest two main results. First, there is evidence of much stronger spillover effects of the US QE policy on financial variables compared to real macroeconomic variables. This result on financial variables is consistent with the narrative of US investors "reaching for yield" in emerging financial markets. That is, as a positive US QE shock brought down long-term yields in the US, capital flows accelerated to emerging market economies, thereby bidding up asset prices such as exchange rates and stock prices and decreasing long-term yields in those countries. Second, the effects on Fragile Five countries are larger compared to the other emerging market economies in our sample. This result is in turn consistent with the narrative of differential effects of US QE policy on emerging market economies, which we relate to pre-crisis, ex-ante fundamentals.

This paper is related to several strands of the literature. There is an active and influential empirical literature, for example, Neely (2010), Gagnon et al (2011), Krishnamurthy and Vissing-Jorgensen (2011), trying to assess the effects of the QE program on interest rates, expected inflation, and other asset prices such as exchange rates.[9] A major approach in this literature is to assess the "announcement effects" of such policies, the response of high-frequency financial variables to the Federal Reserve's announcements of policy changes within a very narrow time frame such as one or two days. By isolating the changes in these variables due to the announcement of QE policy, this literature has shown that such policies most likely contributed to lowering long-term interest rates and depreciating the US dollar.

We contribute to this literature by taking an alternative complementary approach. Our approach allows us to extend the insights from the announcement effects literature by both assessing the impact on broader macroeconomic variables that policy makers focus on, such as output and consumer prices, as well as ascertaining the dynamic effects of such policy. In particular, note that our results for the impact of QE on financial variables, in both the US and the emerging markets, are consistent with the findings of the announcement effect literature. Moreover, our VAR specification allows us to document a strong macroeconomic impact of QE on the US economy.

[9] An incomplete list also includes Wright (2012), Hamilton and Wu (2012), and Bauer and Rudebusch (2013). Rogers et al (2014) is a cross-country empirical study while Fawley and Neely (2013) provides a narrative account of the LSAPs conducted by four major central banks. We focus only on LSAP by the US Federal Reserve.

In taking a VAR-based approach to assess the effects of QE, our paper is related to Wright (2012), Baumeister and Benati (2013), and Gambacorta et al (2014). However, we take a different approach for identification and thus our evidence complements their findings. In particular, our approach is similar to that of Gambacorta et al (2014) who focused on domestic macroeconomic implications of QE by several countries using a central bank balance sheet variable as an instrument of policy. Our identification method, the variables and time period, as well as the focus is however different, as we detail later. Our empirical strategy is also close to the literature that assesses the "purchase effects" of QE policies. For example, D'Amico and King (2013) use a cross-sectional instrumental variables estimation, where Federal Reserve asset purchases are instrumented to avoid endogeneity concerns, to study the effects of large-scale Treasury purchases. Our results on long-term interest rates are consistent with their findings. Their investigation is however limited to high-frequency Treasury yields. Moreover, our method is different in terms of identification and inference as it builds on the conventional monetary policy VAR literature.

There is important work assessing the international effects of US QE policy, for example, Glick and Leduc (2012, 2013), Chen et al (2011), and Bauer and Neely (2013). Our work is different from this research in that we focus on the emerging market economies. Overall, our evidence on the effects on exchange rates and long-term interest rates for these countries is complementary to the international effects documented by these papers on advanced economies. With this focus, using different methods, we are also contributing in the same vein as Eichengreen and Gupta (2013), Aizenman et al (2014), and Bowman et al (2014).[10] Tillmann (2014) uses a Qual VAR that incorporates the Federal Reserve's latent propensity for QE and estimates the effects of QE on the aggregate data of emerging market countries. Our approach is different with respect to identification and the way we pool cross-sectional responses by the emerging market countries. Given our results on international capital flows, our work is also related to Dahlhaus and Vasishtha (2014) and Lim et al (2014), who analyze the effects of the US unconventional monetary policy on capital flows to developing/emerging market economies. Finally, in using a VAR analysis to ascertain the effects of the US monetary policy on international capital flows and asset prices, this paper is also connected to Rey (2013) and Bruno and Shin (2015), who focus on the conventional monetary policy period.

The rest of the paper is organized as follows. Section 2 describes the data and Section 3 describes the VAR methodology. In Section 4 we present the results, first for the US, and then for the emerging market economies. In Section 5, we present robustness exercises and extensions and finally, we conclude in Section 6.

2 Data

We use US macroeconomic and financial data at the monthly frequency from January 2008 to November 2014.[11] We employ the series of securities held outright by the Federal Reserve as a measure of QE/LSAP. It consists of the holdings of US Treasury securities, Federal agency debt securities,

[10] For a case-study based survey on spillovers to emerging market economies, see Lavigne et al (2014).

[11] All the US data is from FRED except for the House Price Index data from Core Logic.

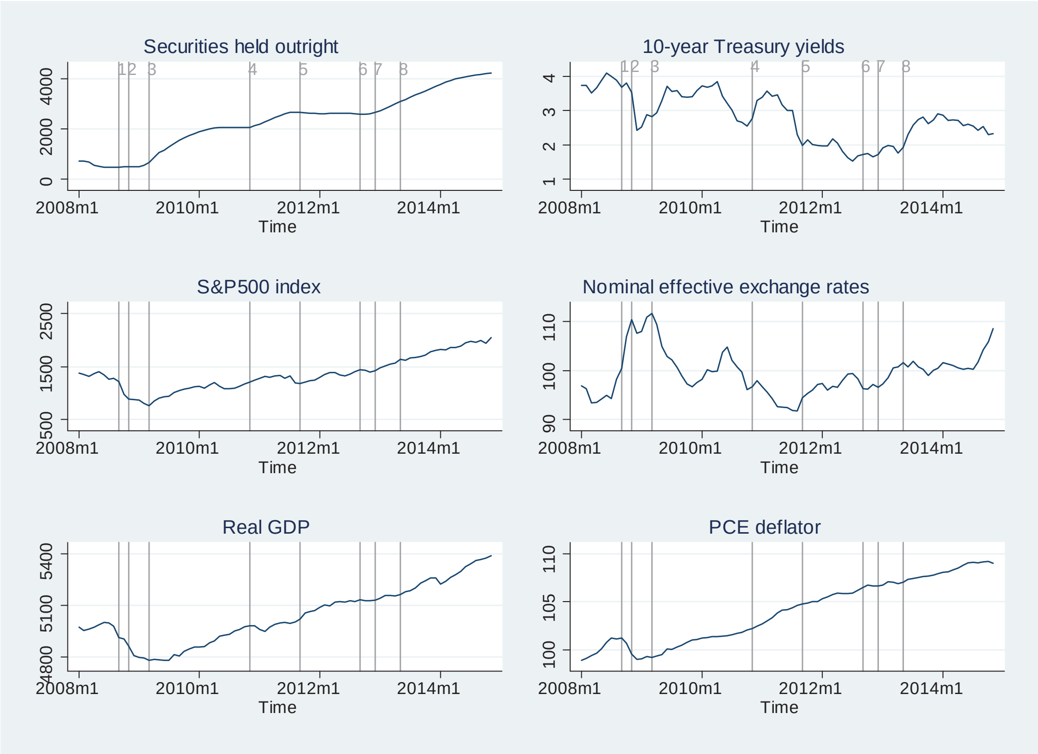


Figure 1: Selected US macroeconomic and financial data

Notes: The vertical lines mark dates of the major events: [1] September 2008 when the Lehman Brothers filed for bankruptcy; [2]-[3] November 2008 and March 2009 which are QE1 dates; [4] November 2010 which is a QE2 date; [5] September 2011 which is an MEP date; [6]-[7] September 2012 and December 2012 which are QE3 dates; and [8] May 2013 when Ben Bernanke discussed the possibility of withdrawal of the QE program at the US Congress. The units are billions of dollars for securities held outright, percentages for 10-year Treasury yields, a 2010=100 index for nominal effective exchange rates, billions of chained 2009 dollars for real GDP, and an 2009=100 index for the PCE deflator, respectively. A decrease in the effective exchange rate means depreciation of the US dollar against a basket of currencies. Real GDP is an interpolated measure. For further details of data, see the data appendix.

and mortgage-backed securities by the Federal Reserve and thus is the most important measure of the size of the asset side of the Federal Reserve balance sheet for our purposes. In particular, these holdings are due to open market operations that constitute outright purchases by the Federal Reserve, which were a main component of QE.[12]

Figure 1 plots securities held outright along with 10-year Treasury yields, the S&P 500 index, nominal (trade-weighted) effective exchange rates, real GDP, and the private consumption expenditures (PCE) deflator. The vertical lines represent the dates of major events including the onset of the Lehman crisis, several phases of quantitative easing by the Federal Reserve, and the taper talk.[13] It is clear that quantitative easing was initiated in an environment where a large negative

[12] We describe this series in more detail in the next section.

[13] 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

shock drove down output and prices. Figure 1 also suggests that after some lag, these interventions likely contributed to driving down long-term interest rates, a stock market boom, and depreciation of the US dollar. The observed comovements of the securities held outright with the other variables, however, do not necessarily imply the causal effects of QE. We aim to isolate and identify such causal effects by careful econometric analysis.

We assess international spillover effects of the US QE policy on the following important emerging market countries: Brazil, Chile, Colombia, India, Indonesia, Malaysia, Mexico, Peru, South Africa, South Korea, Taiwan, Thailand, and Turkey. We collect monthly output, prices, US dollar exchange rates, the stock market index, long-term and short-term interest rates, the bond index, and monetary aggregate data from Datastream and Bloomberg, trade flows data from Direction of Trade Statistics by IMF, and capital flows data from EPFR for the same sample period as the US data.[14]

Figures 2 and 3 document dynamics of long-term interest rates, stock prices, US dollar exchange rates, and cumulative capital flows for these countries. Generally, with the onset of QE in the US and the subsequent expectation of lower long-term US interest rates as shown in Figure 1, emerging market countries experienced a decrease in long-term interest rates and an increase in stock prices as shown in Figure 2 and exchange rate appreciations and capital inflows into their financial markets as shown in Figure 3.[15] Overall, Figures 2 and 3 illustrate some of the international spillovers of the QE policy adopted by the US Federal Reserve. Motivated by these observations, this paper estimates the causal effects of the US QE policy on the emerging market countries.

In addition, to demonstrate a pattern of heterogeneity among emerging market countries evident in the data, we present the data in two subsets of countries in Figures 2 and 3: One for Brazil, India, Indonesia, South Africa, and Turkey, and the other for the rest of the emerging market countries. The first five came to be known as the "Fragile Five" in popular media due to the potential vulnerability of their economies to US QE policy.[16] One goal of showing these data in two subsets is to visualize if there were interesting differences in the data across the countries throughout the QE period and it is indeed noticeable that the swings in long-term interest rates and exchange rates were more drastic for the Fragile Five countries compared to the rest. We will econometrically assess these differences across different country groups in the paper.

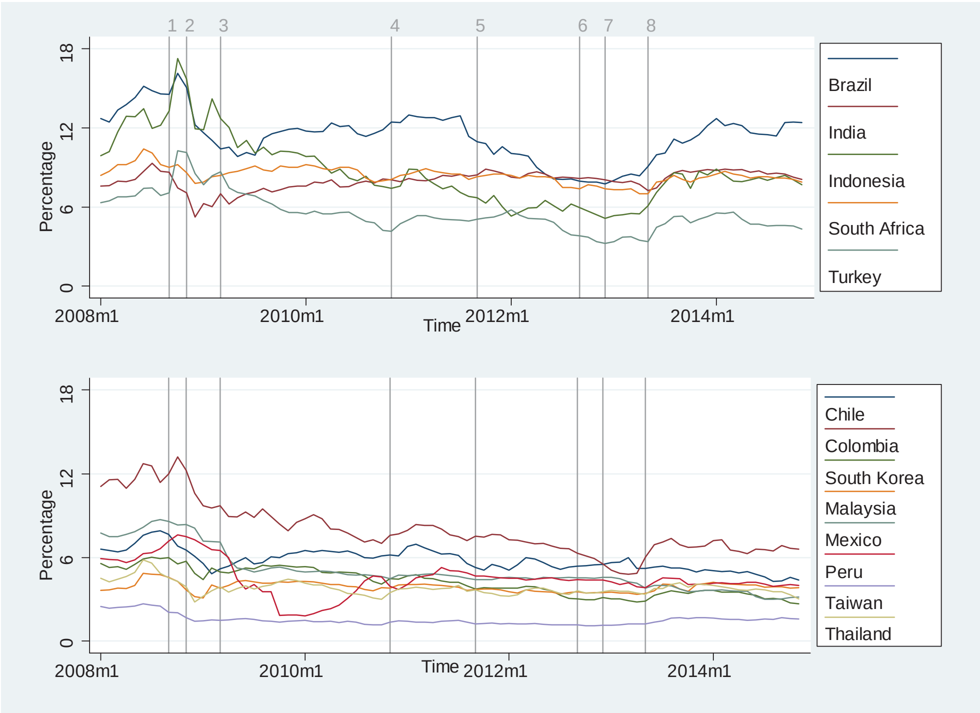
expand its purchases of agency-related securities and to purchase longer-term Treasury securities as well, with total asset purchases of up to $1.75 trillion, an amount twice the magnitude of total Federal Reserve assets prior to 2008. On September 2011, the Federal Reserve announced a new program on 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.

[14] The online data appendix contains a detailed description of data sources for emerging market countries.

[15] In addition, in May 2013, the "taper scare" period, during which financial markets across the globe were surprised by the Federal Reserve's intentions of slowing down its purchases of long-term assets and which in turn led to expectations of tighter policy and higher long-term interest rates in the US, as shown in Figure 1, these emerging market countries experienced a rise in interest rates, a decrease in stock prices, exchange rate depreciations, and capital outflows.

[16] These countries for example, reacted very strongly on May 2013, during the "taper scare," when the possibility of withdrawal of the QE program was mentioned by the Fed Chairman Ben Bernanke.

(a) Long-term interest rates



(b) Stock market indices

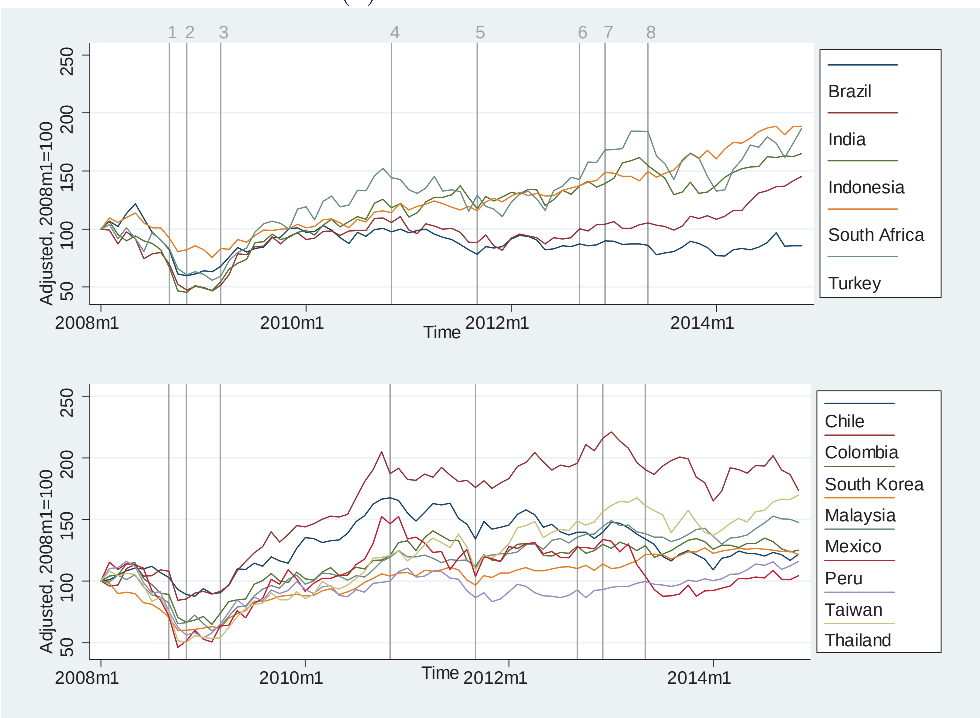
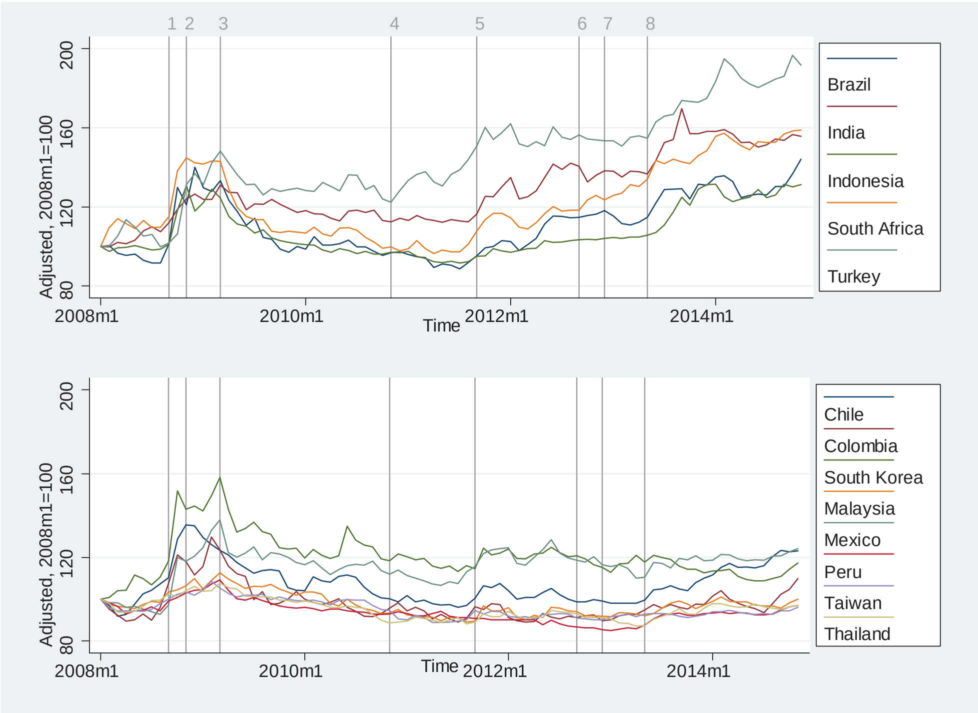


Figure 2: Long-term interest rates and stock market indices in emerging market economies

Notes: Panel (a) presents the long-term interest rates and Panel (b) displays the Morgan Stanley Capital International (MSCI) index for each country, adjusted so that it is equal to 100 in January 2008. For the details of data, see the online data appendix. The vertical lines mark the dates of the major events. For the details, see the notes in Figure 1.

(a) Nominal exchange rates against US dollar



(b) Cumulative capital flows

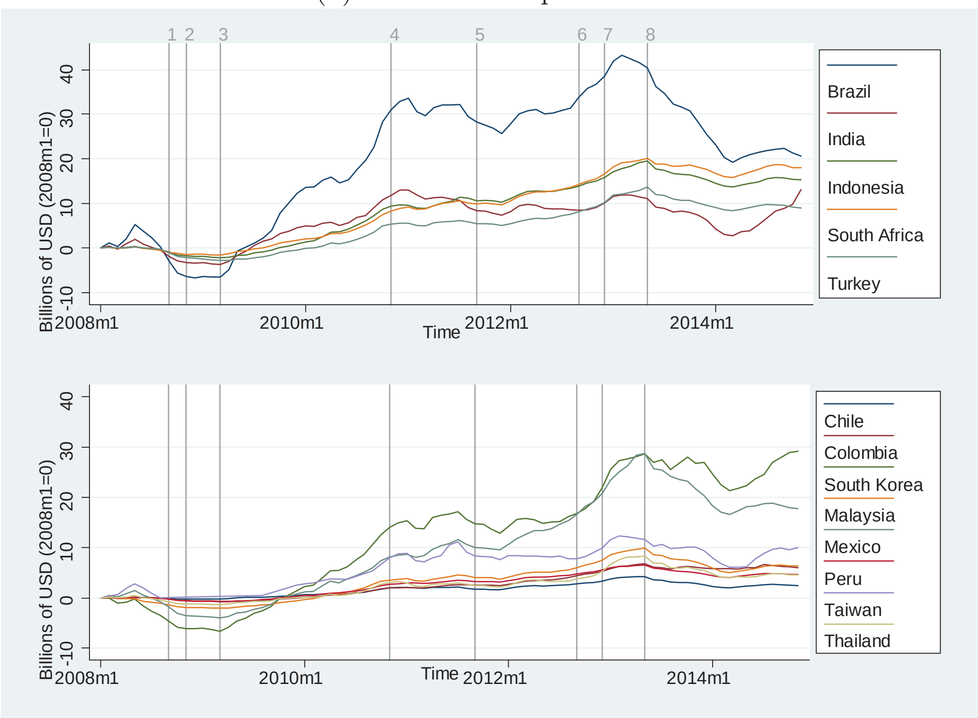


Figure 3: Nominal exchange rates and cumulative capital inflows in emerging market economies

Notes: Panel (a) presents nominal exchange rates against US dollar, the domestic currency price of a US dollar, adjusted so that the exchange rate is equal to 100 in January 2008. Panel (b) shows the cumulative capital flows into each country since January 2008. For the details of data, see the online data appendix. The vertical lines mark the dates of the major events. For the details, see the notes in Figure 1.

3 Empirical methodology

We proceed in two steps in our empirical study. A structural VAR for the US economy is first estimated with US data to identify a QE shock. With this shock included as an external shock, in the second step, a panel VAR for the emerging market countries (EM panel VAR) is estimated to assess the effects of the US QE shock on their economies. We use the Bayesian approach to estimate both the US VAR and the EM panel VAR, whose details including the prior distribution are described below.

3.1 Structural VAR for the US economy

We first describe the baseline specification and identification strategy. We then describe the various extensions.

3.1.1 Baseline specification

For the US economy, we consider a structural VAR model

$$A_0 y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_k y_{t-k} + \varepsilon_t, \tag{1}$$

where y_t is an $m_y \times 1$ vector of endogenous variables and $\varepsilon_t \sim \mathbb{N}\left(0, I_{m_y}\right)$ with $E\left(\varepsilon_t | y_{t-j} : j \geq 1\right) = 0$. The coefficient matrix A_j for $j = 0, \cdots, k$ is an $m_y \times m_y$ matrix.

In our baseline specification y_t includes five variables: the industrial production index as a measure of output, the PCE deflator as the price level, securities held outright on the balance sheet of the Federal Reserve as the monetary policy instrument, 10-year Treasury yields as long-term interest rates, and the S&P500 index as a measure of asset prices. We include the long-term interest rates and stock market price index, unlike much of the traditional VAR literature, as the outcomes and effects on the financial markets were an important aspect of policy making during the QE period.

As mentioned earlier, the size of the Federal Reserve balance sheet measured by securities held outright is considered as the instrument of the QE program after the zero lower bound for nominal interest rates started binding in the US. It consists of the holdings of US Treasury securities, Federal agency debt securities, and mortgage-backed securities by the Federal Reserve. In particular, these holdings are due to open market operations that constitute outright purchases by the Federal Reserve, which were a main component of LSAPs. During normal times, this component of the balance sheet does not vary much as it only used to account for some secular changes in currency demand. Moreover, this measure is only about the size of the asset side of the balance sheet and not its composition.[17] Finally, we chose this component of the balance sheet rather than total assets of the

[17] Note also that during normal times, this measure is not a standard policy instrument as it constitutes what is often called "permanent open market operations." During normal times, the Federal Reserve achieves its target for the Fed Funds rate via "temporary open market operations," using repurchase and reverse repurchase transactions. One phase of QE/LSAPs, the Maturity Extension Program, only constituted a change in the composition and not the size of the balance sheet. Our baseline measure will not account for this phase and to the extent that it had important effects, our estimated effects will be a slight underestimate of the total possible effect of QE.

Table 1: Identifying restrictions on A_0

	Industrial production	PCE deflator	Securities held-outright	10-year Treasury yields	S&P500 index
Prod1	X				
Prod2	X	X			
I	X	X	X	X	X
F	X	X	a_1	a_2	
MP			a_3	a_4	

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. Coefficient a_i $(i = 1, \cdots, 4)$ of A_0 is not restricted except that we impose $Corr\,(a_1, a_2) = 0.8$ and $Corr\,(a_3, a_4) = -0.8$ in the prior distribution.

Federal Reserve as the baseline measure of QE as it is a direct measure of LSAPs, which is the focus of our analysis.[18]

We impose non-recursive short-run restrictions on (1) to identify exogenous variations in the securities held outright, which are referred to as QE shocks. Our identification approach is 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.[19]

Table 1 describes identifying restrictions on A_0 where the columns correspond to the variables while the rows correspond to the sectors that each equation of (1) intends to describe in the US economy. 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 restrictions here are standard in the monetary VAR literature. 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 "MP") in Table 1 are, respectively, the long-run interest rate determination and monetary policy equation. The long-term 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.

For the monetary 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,

[18] In addition to securities held outright, total assets of the Federal Reserve would contain some other components such as gold stock, foreign currency denominated assets, SDRs, and loans. These components are very minor and constant overall during the time period of our analysis, except for a period between Sept 2008 and June 2009 because of an increase in loans made by the Federal Reserve, mostly as primary credit and transactions in liquidity/auction facilities. These components would be distinct from LSAPs, which are our focus. Please see the Federal Reserve H.4.1 Release: Factors Affecting Reserve Balances for further details.

[19] In terms of unconventional monetary policy, our empirical methodology is most related to Gambacorta et al (2014) but there are differences in the variables used, in the identification strategy, and in the time period used in the analysis. They used total assets of the Federal Reserve as the instrument of monetary policy and for identification employed a mixture of sign and zero restrictions in a VAR without long-term yields with data on the early part of the QE program.

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 does not 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. Any unexpected non-systematic variations in the securities held outright are then identified as a shock to the QE policy that is exogenous to the state of the US economy. This approach of isolating QE policy shocks as exogenous variations in the QE policy actions is analogous to that for the identification of monetary policy shocks in the conventional monetary policy analysis.

In order to identify these two last equations separately, we follow Sims and Zha (2006b) and impose an extra prior restriction, known as the "Liquidity Prior," on the otherwise mutually-uncorrelated coefficients of A_0. The Liquidity prior expresses prior beliefs that in the interest rate determination equation ("F"), long-term yields tend to decrease as securities held outright increase (specifically, $Corr\,(a_1, a_2) = 0.8$), while in the policy equation ("MP"), securities held outright tend to increase as long-term yields increase (specifically, $Corr\,(a_3, a_4) = -0.8$). The latter implies a natural restriction that policy makers would purchase more securities in response to a rise in long-term interest rates.[20] Sims and Zha (2006b) imposed this prior to be able to separate out shifts in money demand from money supply in a framework that had both quantity (money) and price (interest rates) variables. We use them for similar reasons as we also have a specification with both quantity and price variables.[21]

3.1.2 Extensions and alternative specifications

We also estimate various extended specifications for the US VAR that include additional interest rates and asset prices. Because of the small sample size, we include one or two additional variables at a time to the baseline specification such as the nominal effective exchange rate, 20-year Treasury yields, corporate bond yields, 30-year mortgage yields, and house prices. We consider monthly GDP and the coincidence index in place of industrial production and CPI in place of the PCE deflator to see whether our results are robust to the choice of the activity measure (including one that contains labor market information) and the price measure. All the identification restrictions in these extensions are detailed later in the paper. Lastly, we try to identify the QE shock using recursive identifying restrictions on A_0 so as to check whether we need our identifying restrictions described in Table 1 to correctly identify the QE shock and lead to results that are economically sensible and consistent with the findings of the related literature.

[20] 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 (for example, those imposed by Gambacorta et al (2014)).

[21] Thus, these prior specifications are useful for us to get meaningful inference on effects of purchases of securities by the Federal Reserve on long-term interest rates. Without these priors results are unstable across specifications in terms of whether a positive QE shock decreases long-term interest rates. Note that in practice, as we show later, only one set of these prior restrictions (those on the long-term interest rate determination equation) are needed to get standard and stable impulse responses, but for the baseline specification we directly follow Sims and Zha (2006b) and use both set of prior restrictions.

3.2 Panel VAR for the emerging market countries

We first describe the baseline specification and identification strategy. We then describe the various extensions.

3.2.1 Baseline specification

After identifying the QE shock from the estimated US VAR, we assess its dynamic effects on the emerging market countries by feeding it into a joint system of equations for their economies. Suppose that our sample includes N countries indexed by i. The dynamics of endogenous variables for country i are represented as

$$z_{i,t} = \sum_{j=1}^{p} B_{i,j} z_{i,t-j} + \sum_{j=0}^{q} D_{i,j} \varepsilon_{QE,t-j} + C_i x_t + u_{i,t}, \tag{2}$$

where $z_{i,t}$ is an $m_z \times 1$ vector of endogenous variables for country i, $\varepsilon_{QE,t}$ is the median of the US QE shock estimated in the US VAR, x_t is an $m_x \times 1$ vector of exogenous variables including a constant term, dummy variables, and some world variables that are common across countries, and u_t is an $m_z \times 1$ vector of the disturbance terms. The coefficient matrix $B_{i,j}$ for $j = 1, \cdots, p$ is an $m_z \times m_z$ matrix, $D_{i,j}$ for $j = 0, \cdots, q$ is an $m_z \times 1$ vector, and C_i is an $m_z \times m_x$ matrix. It is assumed that for $\mathbf{u}_t = \left(u'_{1,t}, \cdots, u'_{N,t} \right)'$,

$$\mathbf{u}_t | \mathbf{z}_{t-1}, \cdots, \mathbf{z}_{t-p}, \varepsilon_{QE,t}, \cdots, \varepsilon_{QE,t-q}, x_t \sim \mathbb{N} \left(\mathbf{0}_{Nm_z \times 1}, \mathbf{\Sigma} \right), \tag{3}$$

where $\mathbf{z}_t = \left(z'_{1,t}, \cdots, z'_{N,t} \right)'$, $\mathbf{0}_{Nm_z \times 1}$ is an $Nm_z \times 1$ vector of zeros, and $\mathbf{\Sigma}$ is an $Nm_z \times Nm_z$ positive definite matrix.

In our baseline specification, $z_{i,t}$ includes four variables: industrial production as a measure of output, the CPI as the price level, M2 as a measure of the monetary aggregate, and nominal exchange rates against the US dollar for each country. M2 is to control for endogenous monetary policy responses of the emerging market countries to the US QE shock. We opt to include M2 as a monetary policy instrument rather than the short-term interest rate mostly because of concerns about data quality and relevance.[22] M2 might also capture some broader monetary policy interventions carried out by central banks of these countries such as foreign exchange interventions. Moreover, some of these countries, such as India, often use multiple measures of interest rates as its policy instrument, thereby making it hard to pick one relevant measure.[23] To the basic three-variable system with output, the price level, and the monetary aggregate, we add US dollar exchange rates to account for the open-economy features of the emerging market economies.

Many of the emerging market countries in our sample are commodity exporters. To take this fact into consideration, a proxy of the world demand for commodities and a price index of commodities

[22] Publicly available data on short-term interest rates of the emerging market countries have several anomalous dynamic patterns such as long periods of time where the interest rate does not change at all.

[23] Countries like Brazil and South Korea use the short-term interest rate as the monetary policy instrument and quality data is available for them. Later, in an extension, we use the short-term interest rate as a monetary policy instrument and show that our main results are robust.

are included in the vector of exogenous variables x_t.[24] In addition, we control for world demand proxied by overall industrial production of OECD countries. 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.[25]

In particular, (3) implies that x_t is exogenous in the system as the emerging market countries under study are a "small open economy" and thus the world variables can plausibly be considered exogenous. Nonetheless, it is likely that there are other common factors that influence the dynamics of these countries. We do not impose any restrictions on $\mathbf{\Sigma}$ in (3) except that it is positive definite so that the disturbance terms $u_{i,t}$'s are freely correlated across countries and could capture the effects, if any, of these other common factors.

Importantly, the coefficient matrices in (2) are allowed to be different across countries. Unlike a common approach for the panel model on the micro data, we allow for such dynamic heterogeneities since the economies of the emerging market countries in our sample have quite different characteristics and thus their dynamics are almost certainly not homogeneous. However, as Figures 2-3 imply, during the crisis period, their major macroeconomic and financial variables exhibited large comovements. Even without any crisis going on in the US, they are small open economies and thus their economies are likely to be driven in a similar way by common world variables. To account for potential common dynamics, and especially effects of the US QE shock that are similar across those countries, we take the random coefficient approach and assume that the coefficient matrices in (2) are normally distributed around the common mean. This approach also allows us to partially pool the cross-country information and obtain the pooled estimator of the effects of the US QE shock on the emerging market countries.

This random coefficient approach is implemented following Canova (2007) and Canova and Ciccarelli (2013). Let us collect the coefficient matrices in (2) as $B_i = \begin{pmatrix} B_{i,1} & \cdots & B_{i,p} \end{pmatrix}'$ and $D_i = \begin{pmatrix} D_{i,0} & \cdots & D_{i,q} \end{pmatrix}'$ and let $\gamma_i = \text{vec}\begin{pmatrix} B_i' & D_i' & C_i \end{pmatrix}'$. Note that the size of γ_i is given as $m_\gamma = m_z m_w$ where $m_w = pm_z + (q+1) + m_x$ is the number of regressors in each equation. We assume that for $i = 1, \cdots, N$,

$$\gamma_i = \bar{\gamma} + v_i, \tag{4}$$

where $v_i \sim \mathbb{N}\left(\mathbf{0}_{m_\gamma \times 1}, \Sigma_i \otimes \underline{\Sigma}_i\right)$ with $\mathbf{0}_{m_\gamma \times 1}$ an $m_\gamma \times 1$ vector of zeros, Σ_i an $m_z \times m_z$ matrix that is the i-th block on the diagonal of $\mathbf{\Sigma}$, $\underline{\Sigma}_i$ an $m_w \times m_w$ positive definite matrix, and $E\left(v_i v_j'\right) = \mathbf{0}_{m_\gamma \times m_\gamma}$ for $i \neq j$.

The common mean $\bar{\gamma}$ in (4) is then the weighted average of the country-specific coefficients γ_i with their variances as weights in the posterior distribution conditional on γ_i's. For a particular value of $\bar{\gamma}$, the pooled estimates of the dynamics effects of the QE shock $\varepsilon_{QE,t}$ can be computed by tracing out the responses of $z_{i,t}$ to an increase in $\varepsilon_{QE,t}$ over time with γ_i replaced by $\bar{\gamma}$.

We note that since we use the median of the US QE shock estimated in the US VAR and its lags

[24] The 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.

[25] In an extension in the appendix, we also control for announcement effects by using dummy variables for announcement dates that we highlighted in the data section.

as regressors in (2), our estimation of its effects is subject to the generated regressor problem. As we show in Section 4, however, the US QE shock is very tightly estimated. Thus the uncertainty around the estimates of the shock is not big and the generated regressor problem is not likely severe. Ideally, we can estimate the effect of the US QE policy in a panel VAR that includes both the US and the emerging market countries with a block exclusion restriction that the emerging market countries do not influence the US economy at all, adopting the "small open economy" benchmark for these emerging market economies.[26] We prefer our two-step estimation because of the time burden to estimate a large panel VAR model for both the US economy and the emerging market countries, which makes it practically difficult to try various alternative specifications and do robustness exercises.

3.2.2 Heterogeneities across subgroups of countries

In addition to the baseline estimation above based on the random coefficient approach, in order to assess economically interesting heterogeneity across subgroups of countries, we implement the following estimation method for two groups of countries in our sample. In this specification, the mean of the coefficients, $\bar{\gamma}$ in (4), is allowed to be different between two groups of countries, denoted group 1 and 2. Specifically, the assumption for the random coefficient approach (4) is modified as follows: For $i = 1, \cdots, N$,

$$\gamma_i = \bar{\gamma}_1 \times I_F(i) + \bar{\gamma}_2 \times [1 - I_F(i)] + v_i, \tag{5}$$

where $I_F(i)$ is an indicator function that takes on 1 if country i is in group 1 and 0 otherwise, $v_i \sim \mathbb{N}\left(\mathbf{0}_{m_\gamma \times 1}, \Sigma_i \otimes \underline{\Sigma}_i\right)$. By comparing the impulse responses to the US QE shock across these two groups, using $\bar{\gamma}_1$ and $\bar{\gamma}_2$, respectively, we can study whether these two groups were differentially sensitive to the US QE shock. Note that, even with the heterogeneity in the mean of the coefficients, equations (2) of all the emerging market countries are estimated jointly and the disturbance terms $u_{i,t}$'s are allowed to be correlated across all the countries. Our baseline sub-group estimation consists of the Fragile Five countries in one group and the rest of emerging market countries in another.

3.2.3 Extensions and alternative specifications

We also assess the impact of the US QE shock on other important variables such as long-term interest rates, stock prices, capital flows, and trade flows in extensions to the baseline specification. Because our sample is not sufficiently large, we extend the four-variable baseline specification by including one additional variable at a time. In our alternative specification, we estimate a panel VAR that includes financial variables only. That is, in $z_{i,t}$, we include M2, US dollar exchange rates, long-term interest rates, stock prices, and capital flows only. This financial panel VAR allows a direct comparison with

[26] Cushman and Zha (1997) is a classic VAR based study of effects of monetary policy in small open economies under the block exclusion restriction. Our approach is similar, but not equivalent, since we do not include the US variables and their lags in the panel VAR for the emerging market countries. We choose not to include the US variables in the panel VAR because of the concern on the degrees of freedom. Instead, in the panel VAR, we control for world variables with the level of the world economic activities proxied by OECD industrial production and the demand for and price of commodities in the world market.

the literature that has focussed on financial markets effects of US QE policy. In another alternative specification we also use the short-term interest rate as a measure of monetary policy instead of M2. Finally, we also consider a different subgrouping of countries in which we include Mexico in the Fragile Five group of countries.

3.3 Estimation details

The frequency of our sample is monthly and it covers the period from 2008:1 through 20014:11. All the data except for interest rates and net exports to GDP ratios are used in logs.

The US VAR includes six lags of the endogenous variables, in the baseline specification and in specifications for robustness exercises, and we use the data in the period from 2008:1 through 2008:6 as initial conditions. The US VAR is estimated using the Bayesian approach with the Minnesota-type priors that are laid out in Sims and Zha (1998) and implemented, for example, in Sims and Zha (2006b). The Minnesota-type prior distribution combines a prior belief that a random-walk model is likely to describe well the dynamics of each variable in a VAR model and a belief that favors unit roots and cointegration of the variables. It is shown to improve macroeconomic forecasts across many different settings by effectively reducing the dimensionality (see, for example, a discussion in Canova (2007)) and widely used as the standard prior for a VAR model with variables that exhibit persistent dynamics like the data in our sample. We choose values for the hyperparameters of the prior distribution following Sims and Zha (2006b). However our results are robust to other values of the hyperparameters, as we report later.

We extract the QE shock as the posterior median of the identified QE shock. The panel VAR for emerging market countries includes three lags for endogenous variables and six lags of the US QE shock. We include only three lags of endogenous variables because of the concern on the degrees of freedom of the panel VAR. Note that the estimated US QE shock is available only from 2008:7 and the first six observations from 2008:7 through 2008:12 are used as initial conditions. The panel VAR is also estimated using the Bayesian approach. A Minnesota-type prior similar to that for the US VAR is also employed for the emerging market panel VAR. In addition, we use the Normal-Inverted Wishart prior distribution that is standard for a Bayesian VAR model and assume that the common mean $\bar{\gamma}$ in (4) and $(\bar{\gamma}_1, \bar{\gamma}_2)$ in (5) follows a normal distribution.

The Bayesian information criterion favors a specification with one lag of the dependent variable for both the US VAR and the panel VAR for emerging market countries. However our sample is quite small and the BIC is known to have poor small-sample properties. Moreover, we do not take the first difference of our data. So we choose to include more than one lag to capture persistent dynamics of the data for both the US VAR and the panel VAR for emerging market economies. Our main results though hold with only one lag of the dependent variable included, as we report later in the appendix.

The Gibbs sampler is used to make draws from the posterior distribution of both the US VAR and the panel VAR for emerging market economies. We diagnose convergence of the Markov chains of

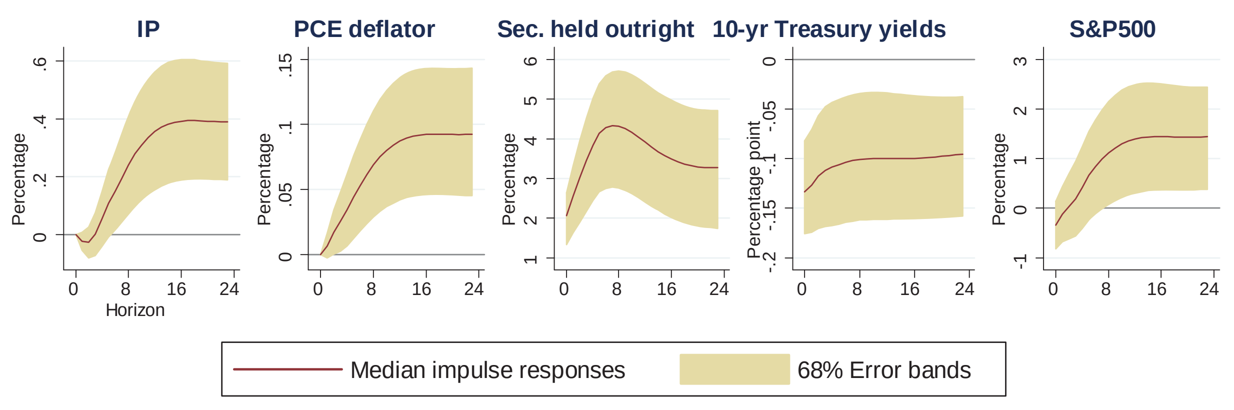


Figure 4: Impulse responses to the QE shock in the baseline specification for the US VAR

Notes: The shock is a one-standard deviation (unit) positive shock in the monetary policy ("MP") equation.

the Gibbs sampler by inspecting the trace plot and computing the Geweke diagnostic.[27] For further details about estimation, see the appendix.

4 Results

We now present our results on the effects of the US QE shock based on the identification and estimation 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.

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 QE shock.

Figure 4 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.[28] Moreover, the financial variables respond: the long term treasury yield falls significantly immediately while stock price increases significantly after a delay following an unanticipated increase in securities held on the balance sheet of the Federal Reserve. Our results on the effects of the US QE shock on long-term interest rates are consistent with the high-frequency based announcement effects or purchase 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

[27]For the US VAR estimation, we used the code made public by Tao Zha. Convergence diagnostics were computed using the *coda* package of R (Plummer et al (2006)). Detailed results of the convergence diagnostics are available on request.

[28]While the identification strategy is different, for real variables, our effects are similar to those in Gambacorta et al (2014).

output. Somewhat differently from that literature, perhaps strikingly so, we also find quick effects on consumer prices. For conventional monetary policy shocks, the VAR literature has documented that significant effects on consumer prices occur after a substantial delay.[29]

How large are the effects of the QE shock? Here is a back-of-the-envelope calculation. A one-standard deviation shock in Figure 4 amounts to about a 2% increase in the securities held outright by the Federal Reserve on impact. This constitutes an increase, on average, of 40 billion dollars in the securities held outright by the Federal Reserve in our sample. In response to a shock of this size, the 10-year Treasury yield falls by around 10 bp on impact. In terms of magnitude, this effect is comparable to the estimated effect of QE2 announcement on long-term yields, as documented in Krishnamurthy and Vissing-Jorgensen (2011). It is also comparable to the estimated effect of QE1 purchases on long-term yields, as documented in D'Amico and King (2003). In addition, we find an effect of around 50 bp on impact on stock prices. Finally, after some lag, we find a peak effect after around 10 months of 0.4% increase on output and 0.1% increase on consumer prices.[30]

The posterior median of the identified QE shock from the baseline VAR for the US, along with 68% error bands, is presented in Figure 5. We rescaled the QE shock and its error bands so that the coefficient on the securities held outright in the monetary policy equation ("MP") of the US VAR has a unit value. Thus it is comparable to the monetary policy shock in the conventional Taylor-type monetary policy rule. The QE shock is quite precisely estimated as reflected in tightness of the error bands. For comparison and to highlight the importance of identification and the need to separate the systematic from the unanticipated component of monetary policy, in Figure 5 we also present the identified US QE shock along with the growth rate in securities held outright and the reduced form QE shock (the shock to securities held outright variable in the VAR). 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 purchase of 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 5 then can be understood as the unanticipated deviation of securities held outright from this prescription of policy, and which is as a result, exogenous to the state 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 purchase of securities to the state of the US economy and thus is not appropriate to estimate the causal effect of unconventional monetary policy.[31] For instance, around March 2009 (QE1), our identified QE shock is much smaller than the growth rate of securities as our method assigns a significant part of the change in securities to the systematic response to the (negative) state of the US economy. Overall our identified QE

[29] For example, we present results later in the paper for the conventional period based on our identification and choice of variables and show that prices respond after quite a delay.

[30] We do not in this paper take a stance on what our empirical results imply for the theoretical mechanisms that have been proposed in the literature to account for the macroeconomic/real effects of quantitative easing. We discuss some of these mechanisms in the conclusion and leave a complete reconciliation of theory with econometric evidence for future work.

[31] Fratzscher et al (2012) take changes in purchases of securities as a direct measure of QE shock, which we feel might be problematic.

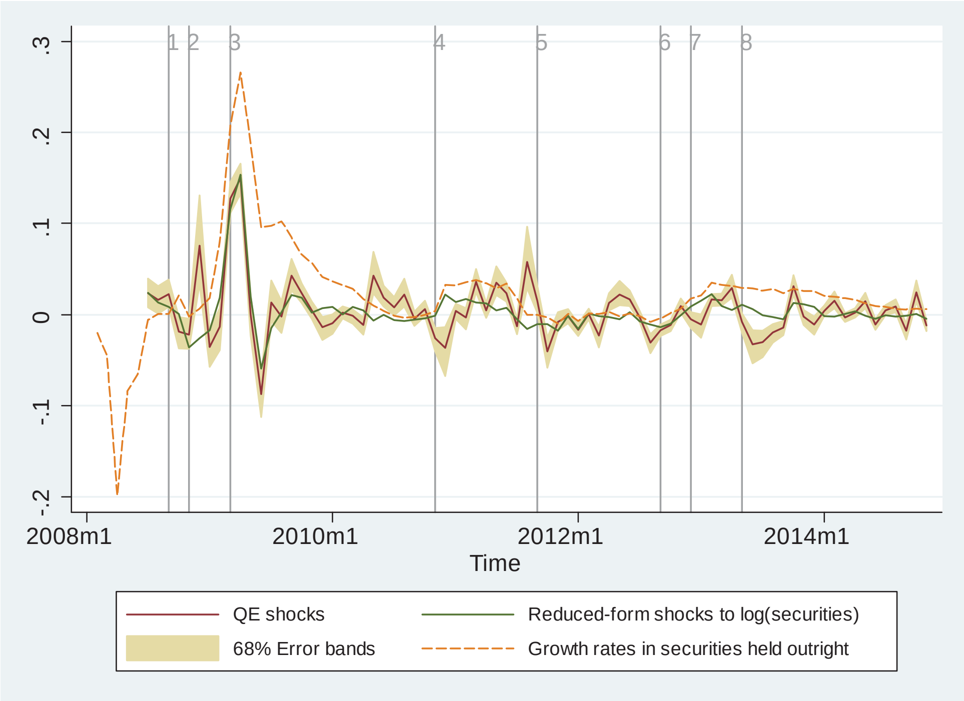


Figure 5: Identified US QE shocks, reduced form shocks to securities held outright, and the growth rate of securities held outright by the Federal Reserve

Notes: The QE shock and the reduced-form shock are the posterior median. The QE shock was rescaled by the coefficient on the securities held outright in the monetary policy equation ("MP") of the US VAR. The vertical lines mark the dates of the major events. For the details, see the notes in Figure 1.

shock series is not perfectly matched with the growth rate of securities held outright though, as to be expected, they co-move to some extent.[32] Note here that while we adopt a "small open economy" benchmark for the emerging market economies, it would still be potentially incorrect to directly use the growth rate of securities held outright as a measure of US quantitative easing in the panel VAR. This is because while the emerging market economies' variables do not influence US variables, a policy measure such as the size of the US Federal Reserve balance sheet is partly endogenous to the developments in the US economy. Thus, using the series as an exogenous variable directly in the panel VAR will lead to incorrect inference. Instead, what we use is the exogenous (according to our identification) component of the size of the balance sheet, or the QE shock, in the panel VAR.

Our shock series is not exactly aligned with important announcement dates of the QE program either. 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. One possible interpretation that can be provided then for our shock series is that we are capturing effects coming from implementation of QE policies. Thus, the interpretation would be similar to the one in the

[32] During the conventional period, monetary policy shock from VARs also co-moves with the actual Fed Funds rate.

Table 2: Variance Decomposition of the Forecast Error

	Industrial production	PCE deflator	Securities held-outright	10-year Treasury yields	S&P500 index
Impact	0.00	0.00	0.55	0.31	0.03
	$[0.00, 0.00]$	$[0.00, 0.00]$	$[0.33, 0.78]$	$[0.1, 0.51]$	$[0.00, 0.06]$
3 month	0.01	0.03	0.51	0.17	0.06
	$[0.00, 0.01]$	$[0.00, 0.05]$	$[0.29, 0.74]$	$[0.02, 0.33]$	$[0.01, 0.12]$
6 month	0.04	0.07	0.50	0.17	0.12
	$[0.00, 0.08]$	$[0.02, 0.13]$	$[0.28, 0.72]$	$[0.01, 0.33]$	$[0.02, 0.21]$
12 month	0.15	0.15	0.38	0.18	0.18
	$[0.04, 0.26]$	$[0.05, 0.26]$	$[0.19, 0.57]$	$[0.02, 0.36]$	$[0.04, 0.33]$

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.

purchase effects of QE literature.[33]

Finally, there is also a difference between the identified and the reduced-form shock, illustrating the role played by our identifying restrictions. Even after removing the predictable responses of the securities held outright to the lagged state of the US economy, there is an additional role played by explicit identification assumptions that isolate the unconventional monetary policy reaction function of the Federal Reserve. Thus, using the reduced-form shock in the panel VAR for emerging markets will lead to different, and possibly misleading, inference on the effects of US QE policy on emerging markets. This is because the reduced form shock will be a combination of the QE shock and various other shocks and cannot be interpreted exclusively as an unanticipated shock to the US QE policy.

Next, 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 2. Similarly to the contribution of the conventional monetary policy shock as documented by the large literature on the conventional monetary policy, 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. On the contrary, it is an important shock that drives securities held outright.

Before presenting our results on the spillover effects on emerging markets, we note that expansionary QE policy has a significant impact on long-term market-based inflation expectations, which is consistent with such statistically and economically significant effects of QE on output and price levels in the US. The role of inflation expectations has received much attention in monetary policy, in particular during the QE period. We therefore assess the effects of the QE shock on inflation expectations using our baseline five-variable VAR specification where we replace stock prices with

[33] Fratzscher et al (2012) also discuss this difference between announcement and actual implementation effects. For an empirical analysis that decomposes the effects of Federal Reserve asset purchases into "stock" vs. "flow" effects, see D'Amico and King (2013) and Meaning and Zhu (2011).

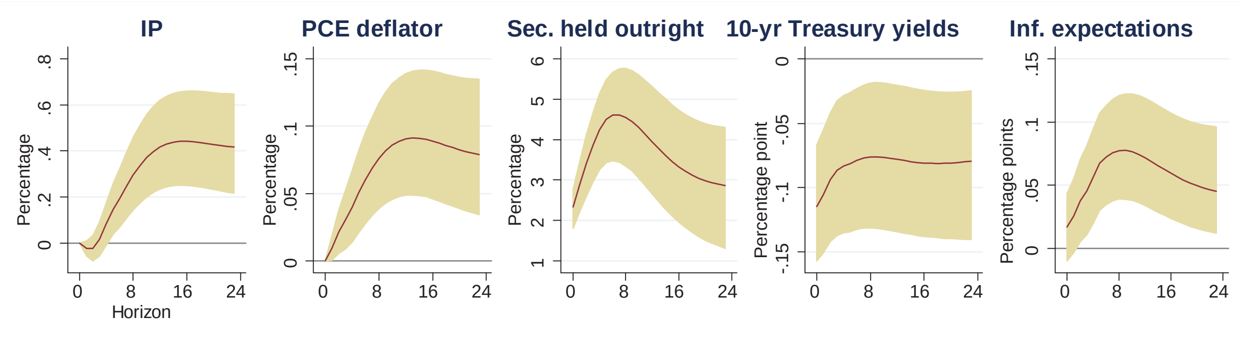


Figure 6: Impulse responses to the QE shock in the baseline specification for the US VAR with 5-year break even inflation expectations

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

5-year break-even inflation expectations.[34] Thus, we include inflation expectation as a fast-moving variable in our VAR and do not change the specification or the identification restrictions in Table 1 in any other way. Figure 6 shows clearly that an expansionary QE shock raises inflation expectations. Thus, the result supports the notion that the QE policy by the Federal Reserve was successful in "anchoring inflation expectations" in the face of a large negative demand shock that would have otherwise led to a negative effect on prices. Finally, note also that by comparing Figure 6 with Figure 4, it is clear that the inference about the effects on other variables does not change from that of the baseline specification that does not include inflation expectations.

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. As described, we partially pool the cross-sectional information across countries and compute pooled estimates of the effects of the US QE shock, which are presented below.

4.2.1 Overall effects

We are first interested in overall dynamic effects of the US QE shock across all the emerging market countries as given by the pooled estimates of the effects computed using $\bar{\gamma}$ in (4). Figure 7 reports the posterior median and 68% error bands of the impulse responses. As we mentioned before, we first estimate the baseline specification with output, prices, the monetary aggregate, and US dollar exchange rates and then estimate extended specifications that include one additional variable at a time. Only the impulse responses of the additional variables, including the stock price, the long-term interest rate, the EMBI index, capital flows and net exports to the US, from these extended specifications are presented in the second row of Figure 7.[35]

[34] The datasource is FRED and the break-even inflation expectations is computed by comparing yields on inflation-indexed (TIPS) and nominal Treasury bonds.

[35] Our inference on the baseline four variables are robust to which fifth variable we include in the extended VAR.

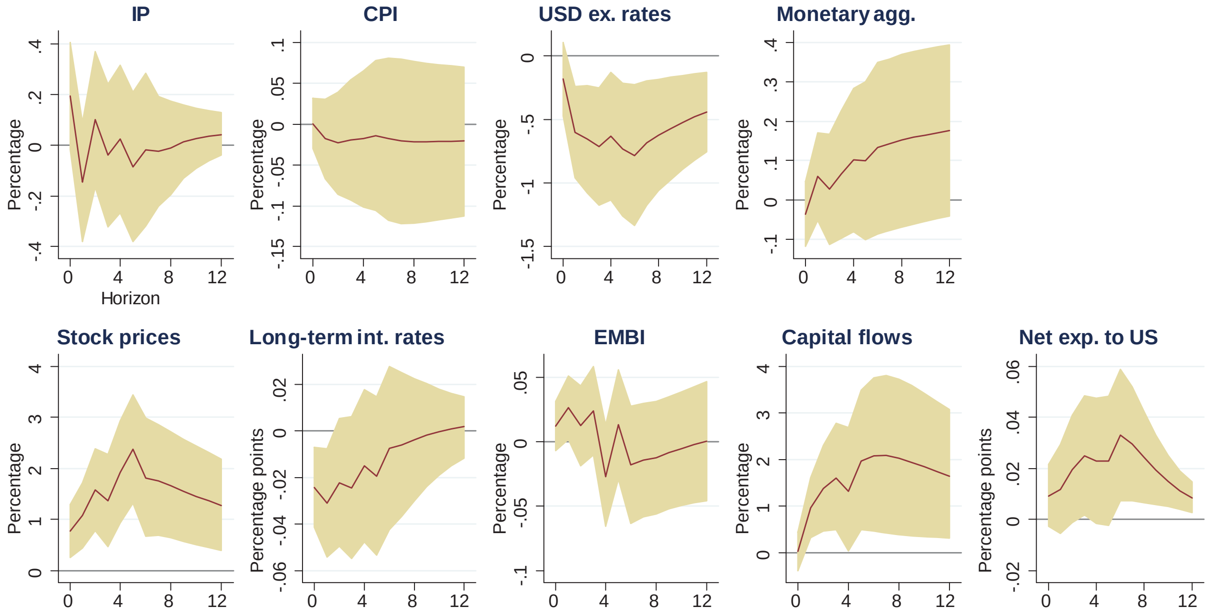


Figure 7: Impulse responses of the panel VAR on emerging market economies

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) increase in the US QE shock identified in the baseline VAR for the US, along with 68% error bands. The first row presents the impulse responses from the baseline specification. The second row presents the impulse responses of each variable from the extended specification that includes the corresponding variable as well as the baseline four variables. USD ex. rates are the domestic currency price of a US dollar for each country. Net exports to the US are the ratio of net exports to the US to GDP of each country. For the description of other variables, see the main text and appendix.

Figure 7 shows that on average, the currencies of these emerging markets appreciate significantly against the US dollar while long-term bond yields decrease in response to an expansionary QE shock.[36] The impact effects on the US dollar exchange rate is around 25 bp and on long-term yields around 3 bp. For the exchange rate, the peak effects are around four times as large as the impact effects and occur after about 5 months. This result confirms anecdotal evidence on the behavior of exchange rates of these emerging market economies that has received significant attentions in the media. In addition, the decline in long term rates is consistent with estimated international spillovers from the announcement effect literature, for example, Glick and Leduc (2012) and Neely (2013), although their sample of countries is not emerging market economies.

The effect on stock prices is also positive and is accompanied by an increase in capital inflows to these countries. The impact effect on the stock price is around 100 bp, with a peak effect of around 200 bp. This is a large effect, comparable to the effect of the QE shock on US stock prices themselves. Capital inflows also increase by a fairly substantial amount, around 2% at its peak. This is also a large (peak) effect. Using the average size of the capital flows in our data, this constitutes

[36] Consistently, the Emerging Market Bond Index (EMBI) increases, but it is not significant.

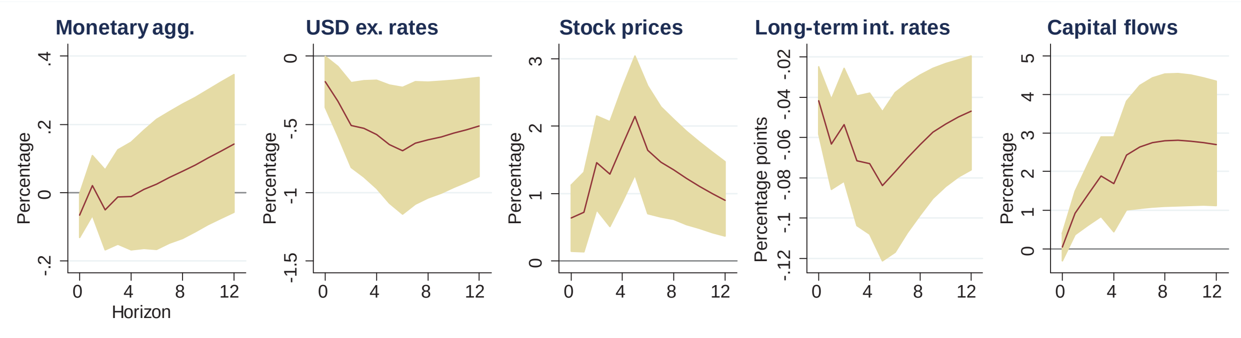


Figure 8: Impulse responses of the panel VAR on emerging market economies with only financial variables

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) increase in the US QE shock identified in the baseline VAR for the US, along with 68% error bands. The impulse responses are from the specification that includes financial variables only.

an average effect of 3.9 billion dollars on the aggregate and 300 million dollars per country. Finally, there are no statistically significant effects on macro variables such as output and consumer prices. For net exports, while the effect is not significant for the first few periods, it eventually increases.[37]

Our results on financial variables is consistent with the narrative of U.S. investors "reaching for yield" in emerging financial markets during the QE period. That is, as a positive US QE shock brought down long-term yields in the US, investors sought higher yielding assets, among which were emerging market assets. Thus, capital flows accelerated to emerging market economies, in the process, bidding up asset prices such as exchange rates and stock prices and decreasing long-term yields in those countries. In this sense, there was an "asset market boom" in these emerging market countries following a positive US QE shock.[38] In spite of these large effects on financial variables, we do not however find robust and significant average effects on the real economy. This is not fully surprising and is in line with possible opposing effects of increased capital inflows on emerging economies, as argued for example recently in Blanchard et al (2015). The results on net exports might be more surprising, as we estimate an appreciation of these currencies, but improved financial and macroeconomic conditions in the US might play a role in the reverse direction.[39]

Next, to highlight the strong effect on financial variables of these countries, and to possibly mitigate some concerns of the small sample bias, we also estimate a panel VAR with monetary aggregate

[37] For conventional US monetary policy shock, Mackowiak (2007) finds effects on exchange rate and interest rates of emerging market economies. Mackowiak (2007) also finds significant effects on output and prices as well, which is not the case for our unconventional US monetary policy shock.

[38] Rapid capital inflows often lead to these developments in small open economies generally. This was true for example for the southern European countries following the introduction of the Euro. For some recent evidence using quarterly data on large effects on house prices and consumption in emerging economies of a global shock, see Cesa-Bianchi et al (2015).

[39] We do control for OECD output in the panel VAR to partly account for this effect, but our controls might not capture perfectly all the relevant variables that impact net exports to the US. Moreover, note that empirically establishing a theoretically consistent relationship between exchange rates and net exports has been a long-standing challenge.

and only four important financial variables: stock prices, US dollar exchange rates, long-term interest rates, and capital flows. This specification arguably allows even a more direct comparison with the announcement effect literature which mostly focusses on effects in financial market variables. The results in Figure 8 show clearly that an expansionary US QE shock appreciates the local currency, decreases the long-term interest rate, increases the stock price in the emerging market countries, and also increases capital flows into their financial markets. Perhaps not surprisingly, the estimates are somewhat more precise in this specification but overall our results are qualitatively consistent across the specification that includes both macro and financial variables and the specification that includes financial variables only. In fact except for some differences in the shape of the response of long-term yields, the results are consistent even quantitatively for other variables across these two specifications.

4.2.2 Fragile Five vs. Others

Now the heterogeneity in the effects of the US QE shock across some economically sensible subgroups of countries is investigated. As we mentioned before, to that end, the mean of the coefficients, $\bar{\gamma}$ in (4), is now allowed to be different between the Fragile Five countries, that is, Brazil, India, Indonesia, South Africa and Turkey, and the rest of the emerging market countries in our sample using the approach in (5). In our notation in (5), let $\bar{\gamma}_1$ be the mean of the coefficients for the Fragile Five countries and $\bar{\gamma}_2$ be the mean for the rest. By comparing the impulse responses to the US QE shock across these two groups, using $\bar{\gamma}_1$ and $\bar{\gamma}_2$, respectively, we can study if these two groups were differentially sensitive to the US QE shock. We can thereby assess the discussions in the media and some vocal statements by policy makers of these countries, as quoted in the introduction, that implied that these five countries were particularly vulnerable to the spillover effects of US QE policy.

The results in Figure 9, using this methodology, show that the effects on financial variables such as US dollar exchange rates, long-term interest rates (and the EMBI), and capital inflows are stronger for the Fragile Five countries compared to the rest of the emerging market countries. The effects on stock prices are similar. In fact, note that for both US dollar exchange rates and long-term yields, the results are barely statistically significant for the non-fragile five countries and for capital inflows, they are not even significant. In terms of the magnitude, the effects on US dollar exchange rates and long-term yields are at least double both on impact and at peak for the Fragile Five compared to the rest. For output and consumer prices however, there are no significant effects on either groups as well as no significant differences across the groups. Moreover, net exports increases for the Fragile Five countries after a delay, and it is not significant for the other countries.[40]

[40] This suggests that the increase in net exports for the entire group above is mostly driven by Fragile Five countries.

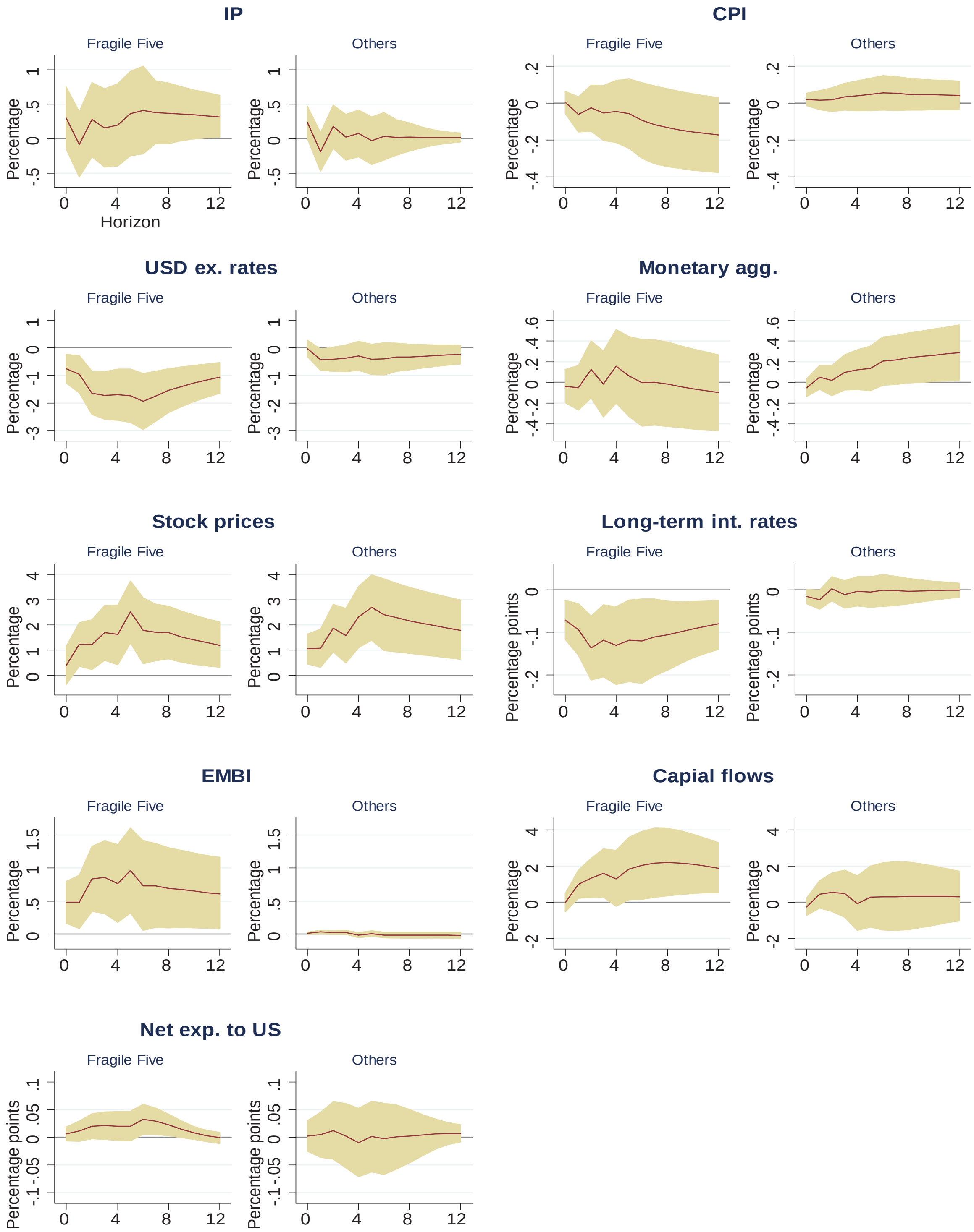


Figure 9: Impulse responses of the panel VAR on Fragile Five and others

Notes: Subplots are arranged by variables and shown for two groups of countries: the Fragile Five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. See the notes in Figure 7.

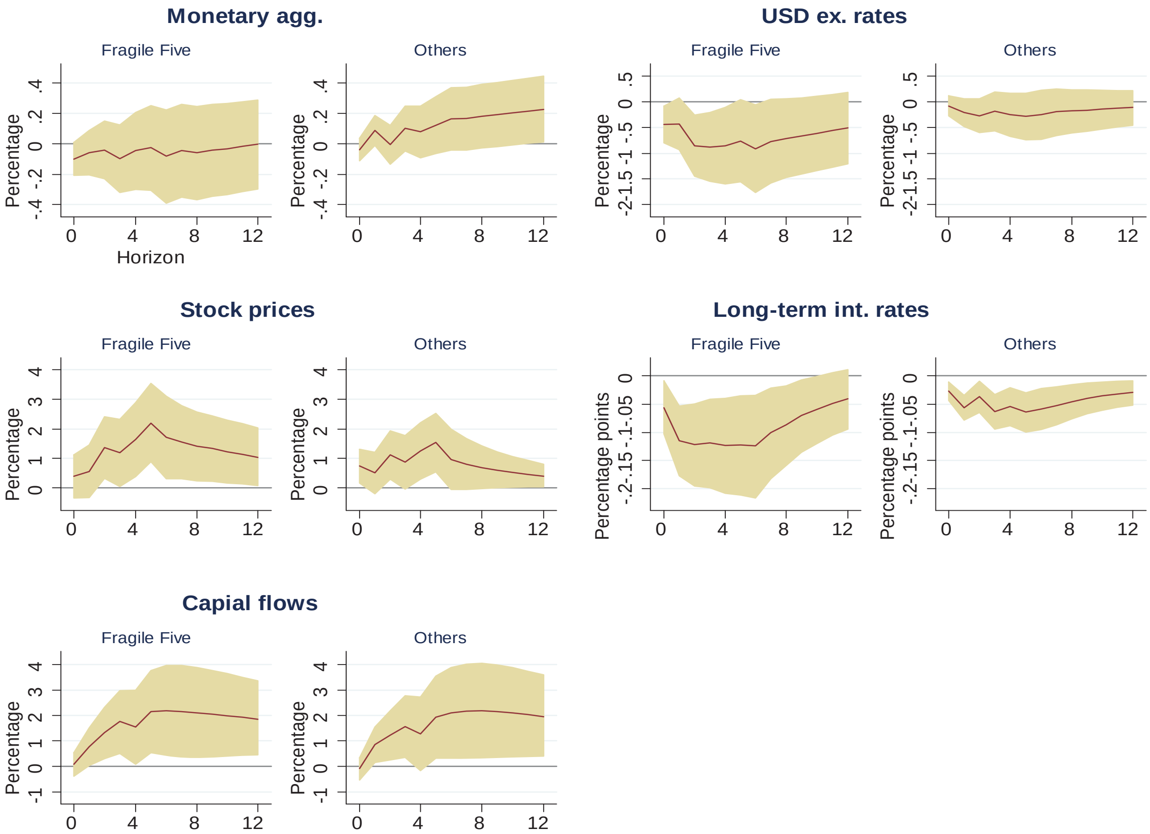


Figure 10: Impulse responses of the panel VAR that includes financial variables only on Fragile Five and others

Notes: Subplots are arranged by variables and shown for two groups of countries: the Fragile Five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. Panel VAR includes financial variables only. See the notes in Figure 7.

We again also estimate a panel VAR that includes financial variables only, with different common means of the coefficients for these two subsets of countries. Figure 10 shows that as before for the entire group of countries, the results are economically similar across the two specifications. The estimates are somewhat more precise here, and thus the effects on long-term interest rates and capital inflows for the non-Fragile Five countries are now statistically significant. Overall the inference is the same: the financial variables respond more strongly for the Fragile Five countries, with a particular difference in the response of the US dollar exchange rate and the long-term interest rate in terms of the magnitude.[41]

[41] In future work, we plan to do a formal model comparison using marginal data densities to assess econometrically these differences between the sub-group model and the all countries model.

4.2.3 Discussion

We now assess what might be underlying fundamental reasons that led the Fragile Five countries to be more sensitive 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 years 2000-2007, for these two groups of countries. Our objective here is to present a picture of the "ex-ante" state of the economy of these countries such that they can be related to the effect of the US QE shock, which was an important external shock for these economies.

In Table 3, we present the average growth rates of the nominal US dollar exchange rate, stock prices, and long-term interest rates for the period from 2000 through 2007. It is clear that during this period, the Fragile Five countries had a more appreciating currency and stock market. Moreover, long-term interest rates especially are much higher in the Fragile Five countries than in the other emerging market countries. Thus, it seems natural that as the Federal Reserve embarked on QE, these countries saw stronger capital inflows as they were more attractive to investors who were going after higher yields with abundant liquidity.

Table 3: Averages of key financial variables in the period of 2000-2007

	Fragile Five Countries	Rest of Emerging Markets
US Dollar Exchange Rates	-0.37	-0.21
Long-term Interest Rates	15.02	4.96
Stock Prices	2.15	1.73

Notes: The monthly datasource is the same as in the panel VAR analysis. The average monthly growth rate for exchange rates and stock prices and the monthly average of long-term interest rates are presented. All the numbers are in percentage.

Table 4: Averages of key imbalance variables in the period of 2000-2007

	Fragile Five Countries	Rest of Emerging Markets
Current Account	-0.57	2.58
Fiscal Balance	-3.66	-1.05
Structural Fiscal Balance	-3.53	-1.35
Government Debt	59.7	34.5

Notes: We take the average of annual data for the two groups. The current account, fiscal balance, and government debt are presented as ratios of GDP while structural fiscal balance is presented as ratio of potential GDP, all in percentage. Government debt is gross government debt. Net government debt is not available for all countries but the average for those available countries follows a similar pattern as gross government debt. The datasource is the World Economic Outlook (WEO) by IMF.

Next, in Table 4, we present some statistics about key external and fiscal "imbalances" for the same period. 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 4 shows 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, relative to GDP.

Our results are similar to Ahmed et al (2015) who also find that the emerging market economies that had relatively better fundamentals to begin with— as measured by a host of individual variables such as current account deficits and government debt— were less sensitive to developments in US QE policy. Our results are also consistent with those in Mishra et al. (2014). We also find that the emerging market economies with ex-ante more "heated-up" asset markets experienced larger private capital inflows and exchange rate appreciations due to a positive QE shock, as was conjectured informally in the media.

5 Robustness and Extensions

We now describe a series of robustness exercises and extensions to the baseline specifications that we have implemented. We first show results obtained in the US VAR that provide an estimate of the QE shock. We then show an important extension in the panel VAR for the emerging market countries where we use the short-term interest rate, instead of the monetary aggregate, to control for the effects of emerging market monetary policy. We also present results based on a different grouping of emerging market economies in the panel VAR.

5.1 Domestic Effects of US QE Shock

We start first with extended results for the US VAR that provides an estimate of the US QE shock and its effects on the US economy.

5.1.1 Additional variables in US VAR

We further assess the effects of a QE shock on financial market variables by extending the baseline US VAR with inclusion of other variables. Figure 11 shows the impulse responses when we include the 20-year Treasury yield in the baseline system to assess the effects on the term structure of interest rates. In terms of identification, we extend the restrictions in Table 1 by including the 20-year Treasury yield in the interest rate determination ("F") sector. We find a robust decline also in the 20-year Treasury yield in response to an expansionary US QE shock, with very similar effects on the 10-year Treasury yield as in the baseline results. Thus, the lowering of Treasury yields was not confined solely to the 10-year horizon, which suggests that the QE shock had an effect on a wide range of the yield curve.[42]

[42] While we do not report them to conserve space, we found a decrease in Treasury yields also at shorter horizons, for example, 3 and 5 year.

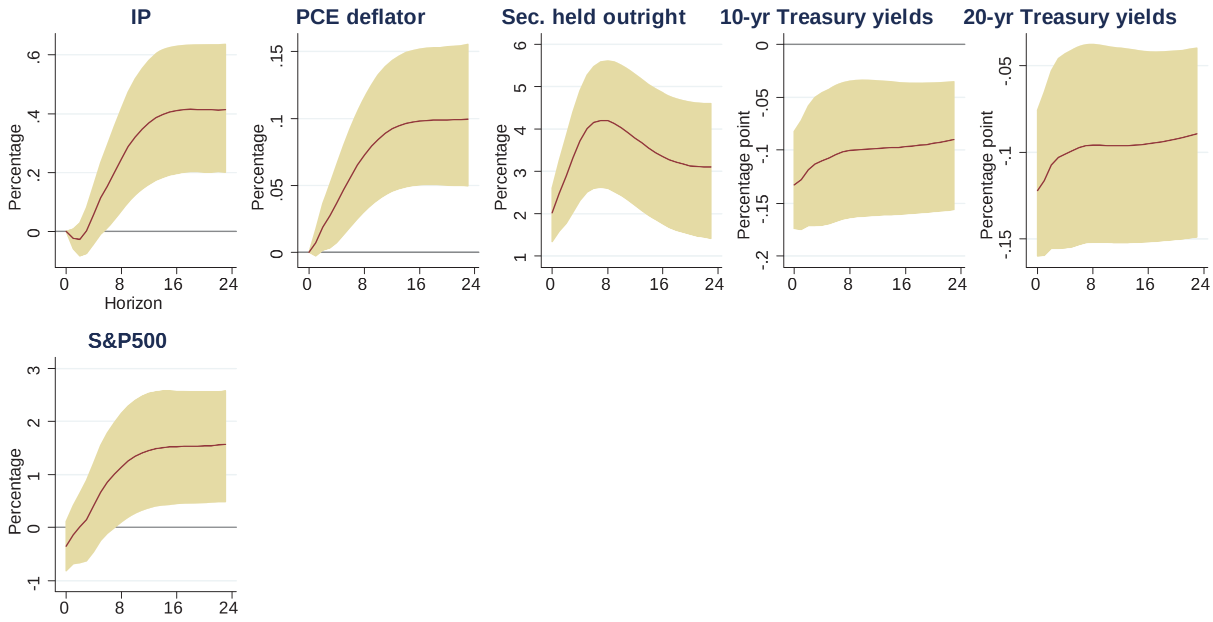


Figure 11: Impulse responses to the QE shock in the extended specification for the US VAR with 20-year Treasury yields

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

We next consider a further extension of our baseline five variable US VAR that is economically interesting. Overall, we seek to assess here the empirical evidence on one of the important stated goals of QE by the Federal Reserve: "Thus, the overall effect of the Fed's LSAPs was to put downward pressure on yields of a wide range of longer-term securities, support mortgage markets, and promote a stronger economic recovery." Moreover, since the previous announcement and purchase effect literature has analyzed effects on financial variables other than 10-year Treasury yields and stock prices, our extensions here will also help further assess consistency of our results with that branch of the literature.[43]

We proceed by adding two important variables in the US VAR: a private sector yield and an additional asset price. For private sector yields, we use 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, includes 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. These variables will help assess whether QE policy had effects generally on financial markets by lowering a wide-range of

[43]Quoted from the answer to the question "What are the Federal Reserve's large-scale asset purchases?" on the Federal Reserve's website.

yields rather than just lowering yields on US Treasuries. For the additional asset price, we consider both the nominal exchange rate and a 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. The effects on the nominal exchange rate will help connect the results with the bilateral exchange rate results we have already established through the emerging markets panel VAR, while the exercise on house prices is a logical extension given the attention the housing sector received in policy making during this period.

In terms of identification, we now include the two private sector yields (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 5. Like earlier in Table 1, Table 5 describes identifying restrictions on A_0 where the columns correspond to the variables while the rows correspond to the sectors.

Table 5: Identifying restrictions on A_0

	Industrial production	PCE deflator	Securities held-outright	10-year Treasury yields	Private yields	S&P500 index	Additional Asset Price
Prod1	X						
Prod2	X	X					
I	X	X	X	X	X	X	
I	X	X	X	X	X	X	X
F	X	X	a_1	a_2			
F	X	X	X	X	X		
MP			$a3$	$a4$			

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. Coefficient a_i $(i = 1, \cdots, 4)$ of A_0 is not restricted except that we impose $Corr\,(a_1, a_2) = 0.8$ and $Corr\,(a_3, a_4) = -0.8$ in the prior distribution.

Figure 12 shows the impulse responses when we extend the baseline VAR with these variables and the identification in Table 5. Panel (a) shows the results where we include a measure of corporate yield and the US nominal effective exchange rate. It is clear that the US QE shock decreases the corporate yield and depreciates the US nominal effective exchange rate.[44] The announcement effect literature that generally focussed on the US dollar exchange rate also has established that QE policies lead to a depreciation. We thus have a similar result here, which is in turn consistent with the bilateral appreciation of the emerging market currencies against the US dollar that we established in the panel VAR. Moreover, note that while actual securities purchases by the Federal Reserve did not directly contain corporate or other private-sector bonds, the results here are in line with the ones from the panel VAR as well as the mechanism that was conjectured during policy making at the Federal Reserve. That is, as asset purchases decreased Treasury yields, investors responded generally by seeking higher yielding assets like corporate bonds (and emerging market assets as we discussed

[44] Unlike for the bilateral exchange rates, for the effective exchange rate, a decrease constitutes a depreciation.

(a) Extension with corporate bond yields and the nominal effective exchange rate (NEER)

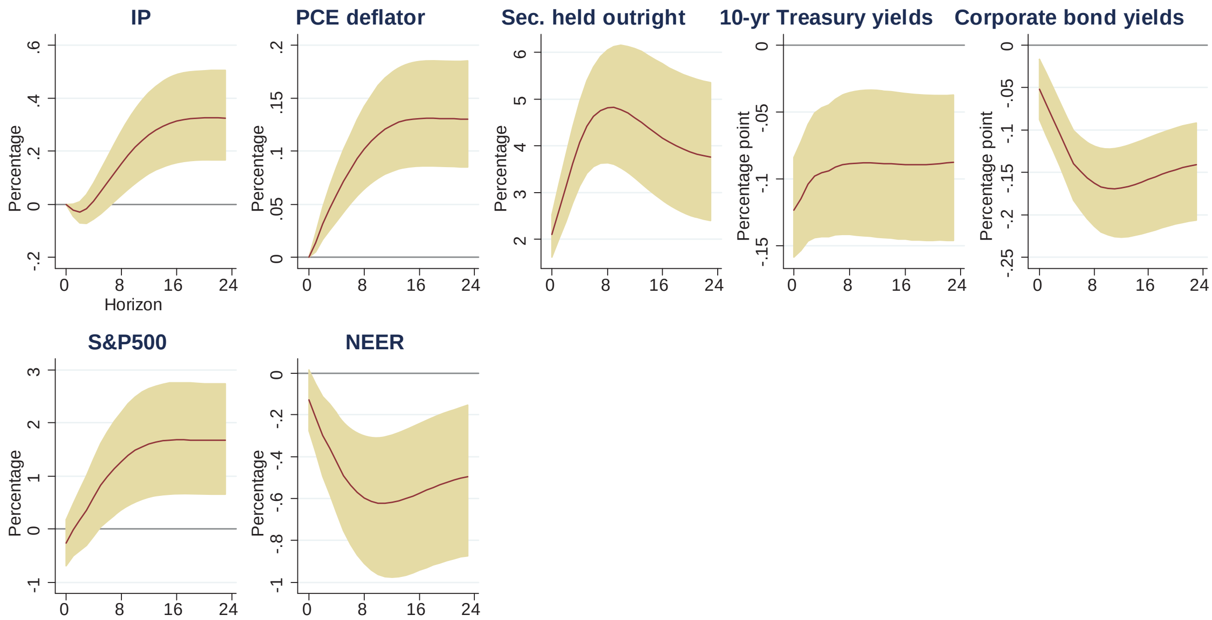


Figure 12: Impulse responses to the QE shock in the seven-variable extended specifications for the US VAR

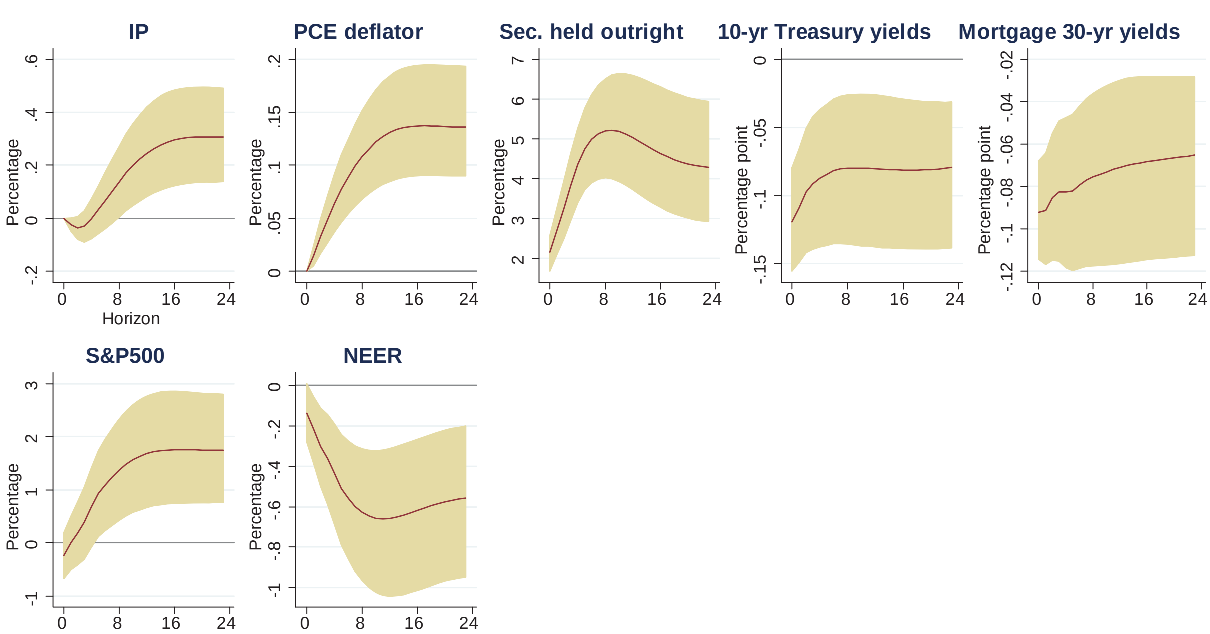
Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

before), thereby bidding up their prices and lowering yields.[45]

Panel (b) of Figure 12 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 decreases the mortgage yield and depreciates the US nominal effective exchange rate. Thus while in the baseline specification we focussed on Treasury yield, here we find that a unanticipated shock to asset purchases by the Fed (which note included purchases of Treasuries, agency debt, and mortgage backed securities) reduced both Treasury and Mortgage yields. Finally, we present our results when we include as private yield the mortgage yield and as an asset price house prices. By focussing on the housing sector, this allows a direct comparison of how the dynamics of mortgage yield and house prices were affected by the US QE shock and whether the results are economically sensible. As to be expected, Panel (c) of Figure 12 shows that the US QE shock decreases the mortgage yield and increases the house price index, in an economically consistent manner.

[45] We do not have enough variation given our time-series approach to assess whether targeted purchases in some sectors (such as Treasuries of certain maturity) affected those yields (such as Treasuries of those maturity) more than yields of other sectors. Using rich cross-sectional data, such issues have been addressed in the announcement effects (for example, Krishnamurthy and Vissing-Jorgensen (2011)) and purchase effects (for example, D'Amico and King (2013)) literature.

(b) Extension with mortgage yields and the nominal effective exchange rate (NEER)



(c) Extension with mortgage yields and house prices

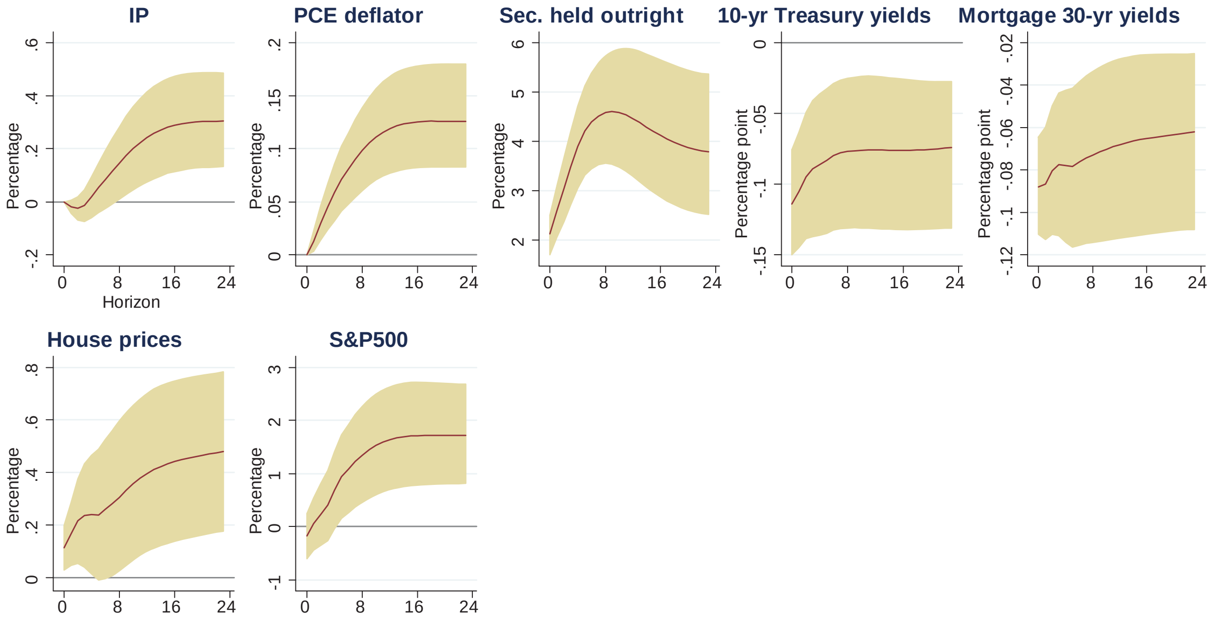
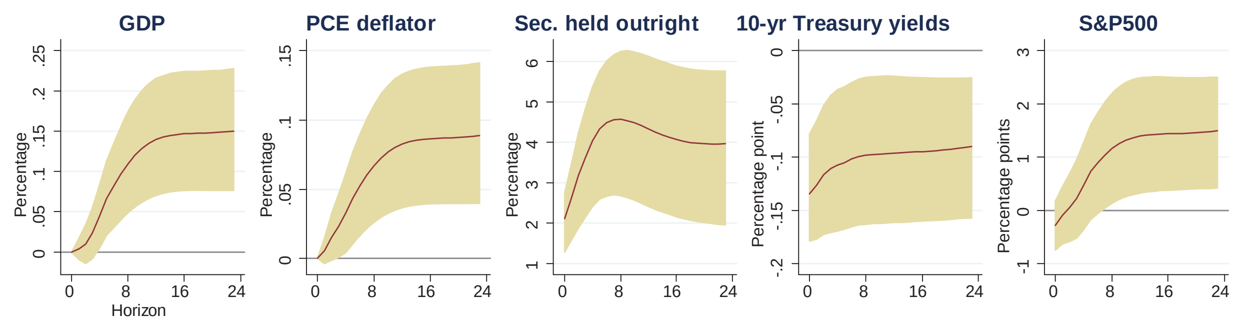


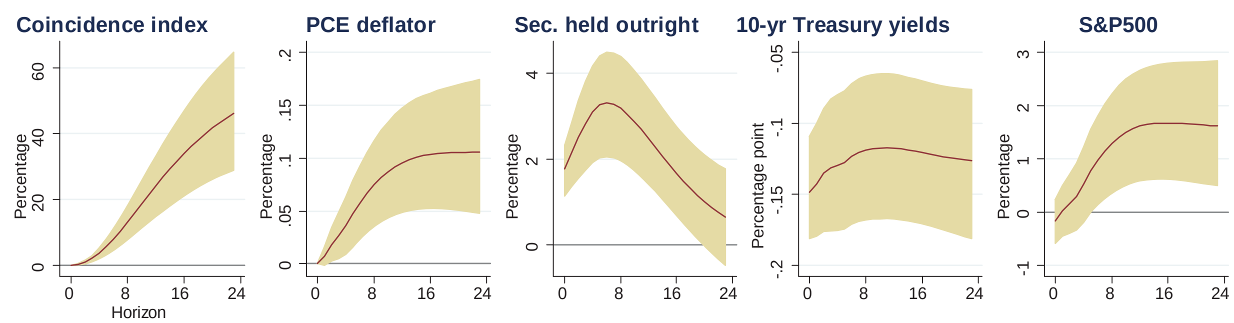
Figure 12: (continued) Impulse responses to the QE shock in the seven-variable extended specifications for the US VAR

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

(a) Robustness exercise with real GDP instead of industrial production



(b) Robustness exercise with the coincident index instead of industrial production



(c) Robustness exercise with CPI instead of the PCE deflator

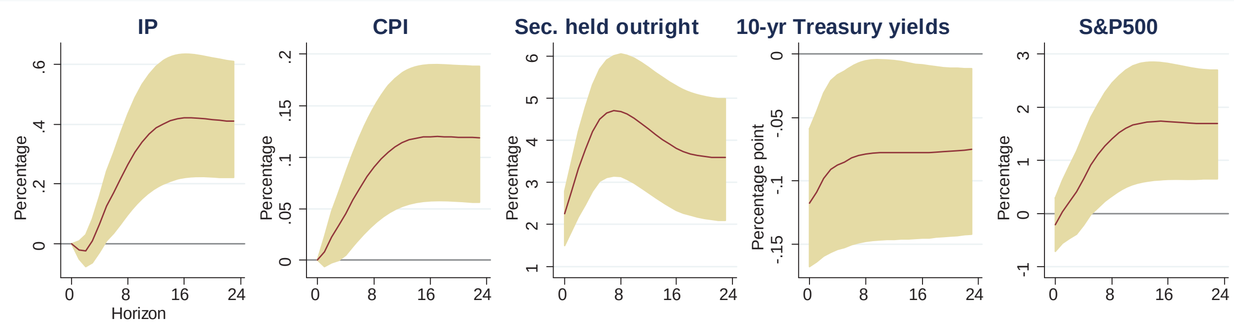


Figure 13: Impulse responses to the QE shock for the US VAR with alternate activity and price measures

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

5.1.2 Other activity and price measures in US VAR

Our baseline measure for output in the US VAR was Industrial Production, which is a standard 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.[46] The results are presented in Panel (a) of Figure 13. Second, to incorporate some information from labor markets,

[46]We use the Chow-Lin procedure for interpolation. The details are in the appendix.

which was important in monetary policymaking decisions, 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 Panel (b) of Figure 13. It is clear from these results that our inference on the effects of the QE shock on US macroeconomic and financial variables does not change. Finally, 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 Panel (c) of Figure 13. 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 US data. Details of these exercises are available on request and we find that our results are largely robust to considering alternative measures of consumption and housing activity, Treasury yields, consumer price, or house prices. In particular, while statistical significance is an issue for some cases, an expansionary QE shock robustly decreases Treasury yields and increases output and prices. In the appendix, we present some of the results related to using additional measures of consumption as well as housing activity. We have also undertaken a robustness exercise where we include VIX as a fast-moving variable in the VAR and find that while the effects on VIX of the QE shock are insignificant, the effect on stock prices is positive and significant as in the baseline specification.

5.1.3 Recursive identification

We have used non-recursive restrictions on the A_0 matrix for identification of the US QE shock. Another widely used identifying assumption in the empirical (conventional) monetary policy literature is a 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 6.

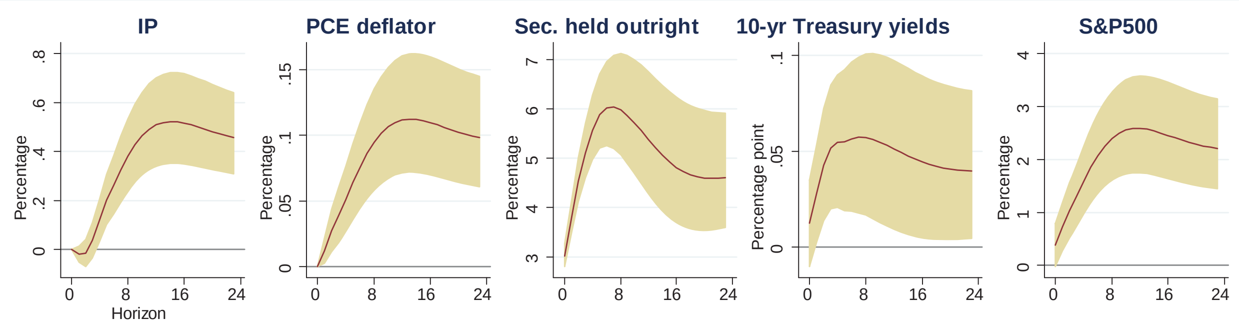
Table 6: Identifying recursive restrictions on A_0

	Industrial Production	PCE deflator	Securities (10-year yields)	10-year yields (Securities)	S&P500
Industrial Production	X				
PCE deflator	X	X			
Securities (10-year yields)	X	X	X		
10-year yields (Securities)	X	X	X	X	
S&P500	X	X	X	X	X

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. The liquidity prior is appropriately applied to the equation with the fourth variable.

To make the restrictions as close to our baseline identification strategy as possible, we could

(a) Recursive identification with 10-year Treasury yields ordered after Securities held outright



(b) Recursive identification with 10-year Treasury yields ordered before Securities held outright

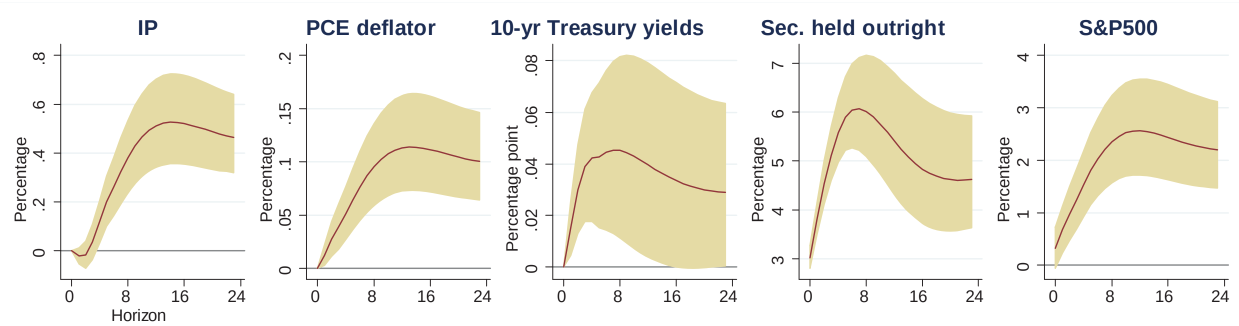


Figure 14: Impulse responses for the US economy with a recursive and non-recursive identification and one liquidity prior

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy equation, along with 68% error bands.

use two possible ordering of variables. In both, it is natural to have Industrial production ordered 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 implies that the Federal Reserve would not respond to the long-term interest rate contemporaneously, while in the latter, it implies 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 at a time.

Panels (a) and (b) of Figure 14 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 as well as much empirical evidence based on other approaches. Based on these results, we thus conclude that the non-recursive restrictions on the A_0 matrix are indeed the appropriate identification strategy for the QE period.

(c) Non-recursive identification with one liquidity prior only

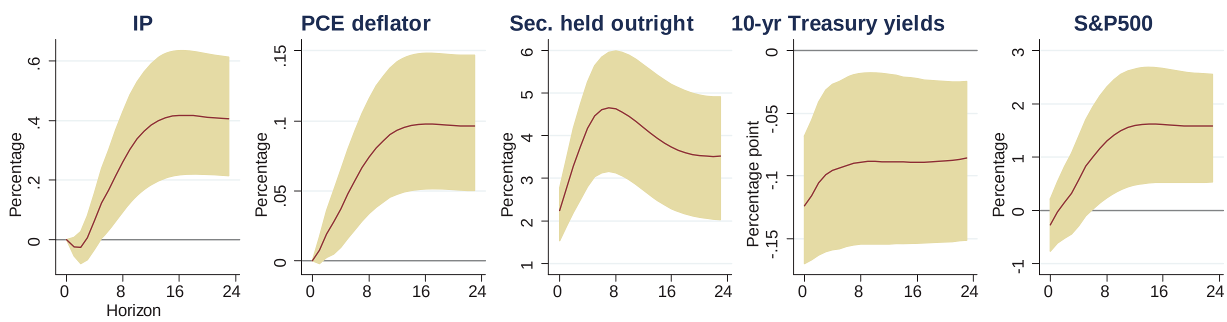


Figure 14: (continued) Impulse responses for the US economy with a recursive and non-recursive identification and one liquidity prior

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy equation, along with 68% error bands.

One might still wonder if in addition to the differences in identification whether liquidity priors also are responsible for the differences in results between the non-recursive and recursive restrictions. This is a legitimate concern as for the recursive identification method, only one set of liquidity priors can be applied. We show below however, that this does not drive our results. In particular, Panel (c) of Figure 14 shows the results from our baseline specification where we only impose one set of liquidity priors, that on the long-run interest rate determination equation (thus, we have $Corr\,(a_3, a_4) = -0.8$). Then, these results are directly comparable to Panel (a) of Figure 14 as the only difference is the identification strategy. It is clear from Panel (c) of Figure 14 that the non-recursive identification method continues to give economically meaningful and sensible results even with only one of the (and common to both) liquidity priors. Thus, for the identification of a QE shock, non-recursive and recursive restrictions give economically different results.

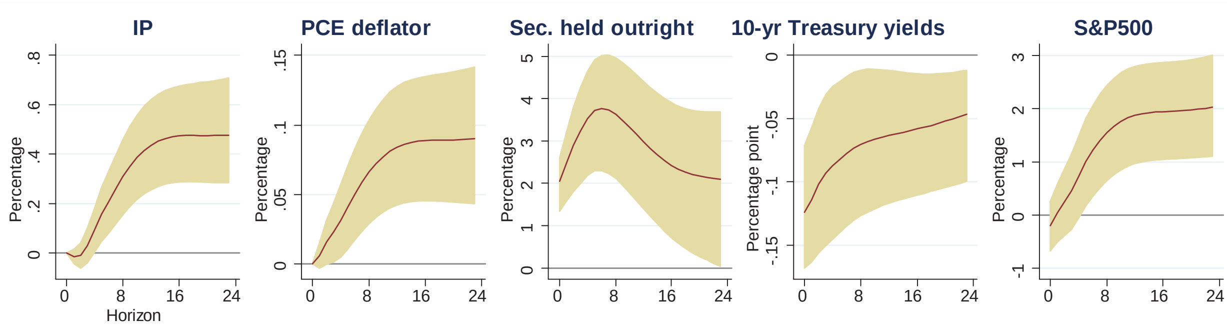


Figure 15: Impulse responses to the QE shock in the baseline specification for the US VAR with loose priors

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

5.1.4 Sensitivity to priors in US VAR

We now assess the robustness of our US results to the prior specifications, especially with respect to the long-run behavior among the variables. Our baseline specification uses the same values for the hyperparameters of the Minnesota-type prior distribution as in Sims and Zha (2006b). Since the response of some variables shows high persistence, however, we loosen two of the hyperparameters that determine the tightness of prior beliefs related to unit root and cointegration properties among the variables.[47] Figure 15 shows that the responses of securities held outright and 10-year interest rates are somewhat muted with looser prior beliefs compared to the persistent responses of those variables in Figure 4. However, our main results, in particular inference on short and medium term effects on macro variables and long-term interest rates, are robust to this change. Moreover, the other variables still respond persistently.[48]

5.1.5 Conventional period US VAR

Finally, for comparison with a large literature, we identify a US monetary shock during the conventional time period (from 1965 to 2007) with non-recursive restrictions and a very similar set of variables as those in the baseline specification. This helps us assess whether our identification scheme as well as inclusion of variables like stock prices (which do not always appear in monetary VAR studies) leads to non-standard results during the conventional time period. For this purpose, we will assume, as is standard, that the Federal Funds rate constitutes the monetary policy instrument, but we use a measure of money in the VAR as well.[49] Table 7 describes identifying restrictions on A_0 where the columns correspond to the variables while the rows correspond to the sectors. Here, the appropriate liquidity priors constitute $Corr\,(a_1, a_2) = 0.8$ and $Corr\,(a_3, a_4) = -0.8$.[50]

Figure 16 shows the impulse responses for the baseline system.[51] Our results are very standard and accord with conventional wisdom. Following an expansionary monetary policy shock, output increases relatively quickly while prices increase only after a significant delay of around ten periods. Moreover, M2 increases while the stock market booms as well. Note here that the effects on stock prices of monetary policy are positive and significant, but not as strong and long-lasting as during the QE period.[52] Based on these results, we emphasize that a set of variables and identification strategy very similar to the one we used for the QE shock would lead to standard inference for the conventional monetary policy shock. The variance decomposition results, which are also consistent with the literature, as well as the results based on a recursive identification are in the appendix.[53]

[47] Details of the hyperparameters are explained in the appendix. We change both μ_4 and μ_5 from 5 to 2.

[48] The strong persistence might be due to the overall persistent dynamics of output and prices during this period, in particular, with what appears to be a somewhat permanent shock around 2008-2009.

[49] In particular we use M2 for the monetary aggregate.

[50] Our identification is overall very similar to that in Sims and Zha (2006a and b). In particular, as in Sims and Zha (2006b), there is an assumption of a standard money demand type equation as well as an assumption that monetary aggregate (with interest rates responding positively to increases in money) enters the central bank reaction function.

[51] As is standard in the identified VAR literature, again we show 68% error bands.

[52] Using looser priors from the baseline, like we do for the QE period, does not change our results.

[53] The variance decomposition results show that compared to the QE shock, the conventional monetary shock explains more variation in output and less in consumer prices and stock prices at a one-year horizon. The recursive identification

Table 7: Identifying restrictions on A_0

	Industrial production	PCE deflator	Federal Funds Rate	Monetary Aggregate	S&P500 index
Prod1	X				
Prod2	X	X			
I	X	X	X	X	X
F	X	X	a_1	a_2	
MP			a_3	a_4	

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. Coefficient a_i $(i = 1, \cdots, 4)$ of A_0 is not restricted except that we impose $Corr\,(a_1, a_2) = 0.8$ and $Corr\,(a_3, a_4) = -0.8$ in the prior distribution. These identifying restrictions are for a standard monetary policy shock during the conventional period.

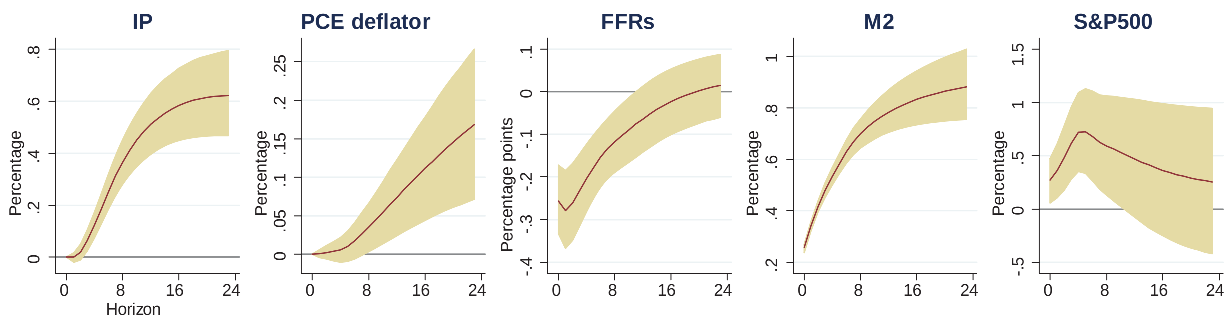


Figure 16: Impulse responses to the conventional monetary policy shock in the baseline specification for the US VAR

Notes: Each plot displays the posterior median of the impulse responses to a one-standard deviation (unit) shock in the monetary policy ("MP") equation, along with 68% error bands.

In future work, we plan to also asses the effects of the conventional US monetary shock on (at least some of) these emerging market countries in a panel VAR framework.[54] This will help us relate our results to other papers such as Canova (2005) and Mackowiak (2007).[55]

5.2 Spillover Effects of US QE Shock

We now provide two sets of important additional results on the emerging markets panel VAR, one where we use the short-term interest rate instead of the monetary aggregate and another, where we consider an alternate sub-grouping of countries. Robustness related to lag length and inclusion of

leads to a well-known price puzzle: following a contractionary monetary policy shock, inflation rises a period after impact and for several periods thereafter.

[54] The limited data availability over this time period for several key variables such as long-term interest rates and capital flows, as well as exchange rate regime changes and even crisis in many of these countries has precluded a straightforward analysis currently. We leave it for future research to perhaps conduct a sub-sample study for a subset of the emerging market countries.

[55] Kim (2001) is another important paper in the literature on the international effects of U.S. conventional monetary policy, but his focus is on G-6 countries.

dummies for announcement dates are in the appendix.

5.2.1 Short-term interest rate as a monetary policy instrument

In the baseline panel VAR a measure of the monetary aggregate was included to capture and control for monetary policy in the emerging markets. While this is our preferred specification, we now instead use a measure of short-term interest rates and repeat the panel VAR analysis. This is because some of the emerging market countries in our sample, such as Brazil and South Korea, implement monetary policy by adjusting short-term interest rates rather than monetary aggregates. We start first with the baseline results that use all countries. We then move on to the sub-group analysis where the Fragile Five countries constitute one group and the rest of emerging markets another.

Figure 17 presents the results based on the estimated average effects across all emerging market economies in our sample. As is clear, our inference is the same as that from Figure 7 for financial variables: An expansionary US QE shock leads to an appreciation of the currencies of these countries against US dollar, an increase in stock prices, a decrease in long-term interest rates, as well as an increase in capital inflows. Moreover, on the macroeconomic front, there are no significant effects on output and consumer prices, but net exports to the US increase. In addition, even in terms of the magnitude, the results are basically the same as in Figure 7, with stronger estimated effects on capital flows.

We next also estimate the financial panel VAR that does not include macro variables. Figure 18 shows the response of the variables and again our inference is the same as in Figure 8: An expansionary US QE shock leads to an appreciation of the currencies of these countries against US dollar, an increase in stock prices, a decrease in long-term interest rate, as well as an increase in capital inflows. Like in Figure 8, the response of the long-term interest rates is more precise and bigger compared to the baseline panel VAR that includes macroeconomic variables. One quantitative difference here is that the effects on capital flows are imprecisely estimated.

Using the short-term interest rate instead of the monetary aggregate, we now present results based on sub-group estimation where the Fragile Five countries constitute one group and the rest of emerging markets constitute another. Figure 19 shows that the Fragile Five countries respond more strongly, in particular their exchange rate appreciates more and long-term interest rates fall by a larger amount. Moreover, capital inflows increase significantly more for them, with an imprecise and weak response of the Non-Fragile Five. The response of stock prices is comparable across the groups and the rise of net exports is only a feature of the Fragile Five. Thus, these results are both qualitatively and quantitatively the same as in Figure 9.

Finally, we repeat this sub-group analysis for the short-term interest rate and the financial variables. Figure 20 presents the results. It is clear that like above, the response of the financial variables is stronger for the Fragile Five countries and, in particular, that of the US dollar exchange rate, long-term interest rates, and capital inflows. Moreover, in terms of the magnitude, the effects are very similar to those in Figure 10.

Overall, this comparison leads us to conclude that while using the monetary aggregate is our

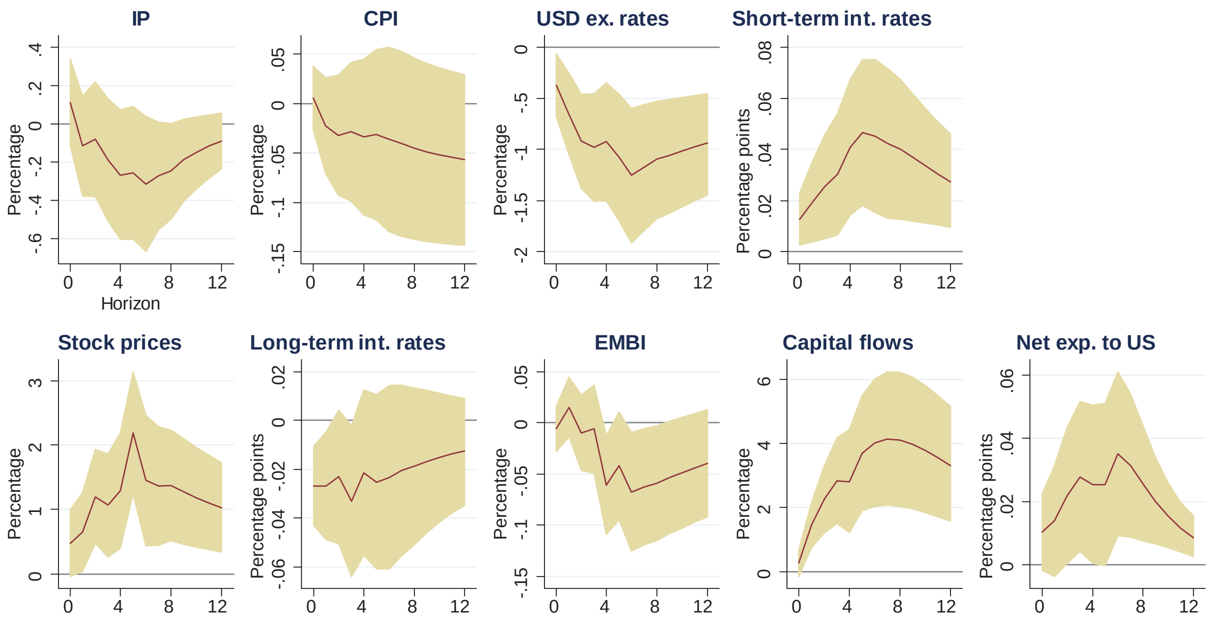


Figure 17: Impulse responses of the panel VAR on emerging market economies that includes the short-term interest rate

Notes: Results are from a specification that uses the short-term interest rate instead of the monetary aggregate in the panel VAR. See also notes in Figure 7.

baseline specification, the substantive aspects our results do not change if we use the short-term interest rate instead to control for monetary policy actions by these countries (despite our concerns on poor quality of the data on short-term interest rates). While there are some differences in the precision of estimates for some variables, our results are robust on balance.

5.2.2 Alternative country groups in the emerging markets VAR

Motivated by discussions in the media and policy circles, so far, we considered two sub groups of countries in an extension of the panel VAR analysis: Fragile Five and rest. Arguably, this grouping is somewhat ad-hoc. We here consider an alternate country group where we add Mexico to the group of Fragile Five countries as it has strong linkages with the US.[56] In Figure 21 we present the results. Comparing with Fig 9, it is noticeable that the responses of financial variables to the US QE shock, in particular, the exchange rate, long-term interest rates, and capital inflows are stronger and more precisely estimated for this group that includes Fragile Five countries as well as Mexico. Even so, for output and consumer prices, there are no significant effects of the US QE shock. For conciseness, we present the results of the financial panel VAR for this sub-grouping in the appendix. The results

[56] As mentioned before, in future work, in an econometrically rigorous fashion, we plan to conduct a Bayesian model comparison to check model-fit, as given by the marginal data density, for this alternate grouping compared to the case of Fragile Five vs. rest and the baseline case of all countries.

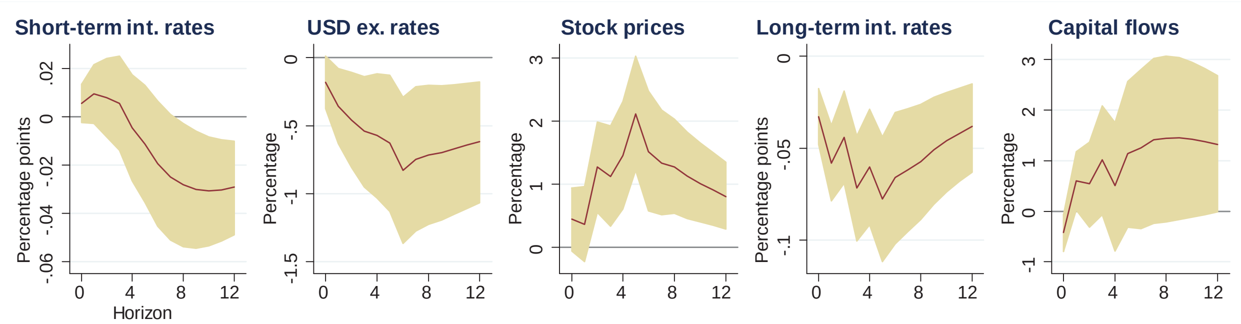


Figure 18: Impulse responses of the panel VAR on emerging market economies with only financial variables that includes the short-term interest rate

Notes: Results are from a specification that uses the short-term interest rate instead of the monetary aggregate in the financial panel VAR. See also the notes in Figure 8.

are similar as here in that the financial variables of the group that includes Fragile Five and Mexico get affected more strongly by the US QE shock.

6 Conclusion

In this paper we estimate the spillover effects of US Quantitative Easing (QE) on emerging market economies. Using a VAR with a 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 and long-term market-based inflation expectations. 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 capital 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 output and consumer prices of the 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 empirical facts that can guide open economy models of unconventional monetary policy transmission mechanisms and spillovers.[57] While doing so, various mechanisms proposed in the closed-economy literature for why QE policies have domestic macroeconomic effects can be extended to an open economy setting with a core-periphery structure to account for spillover effects on emerging markets. Closed-economy mechanisms that generate domestic effects of QE are for example, those that work through credit intermediation (Gertler and Karadi (2011)), portfolio balance effects (Chen et al (2012)), provision of scarce collateral (Williamson (2012)), or signalling of future lower interest rates (Bhattarai, Eggertssson, and Gafarov (2015)). We also plan to quantitatively reconcile these mechanisms with our estimates of the domestic effects of the US QE shock.

[57] One can use these results to extend standard open economy models such as Corsetti and Pesenti (2005) and Clarida, Gali, and Gertler (2002).

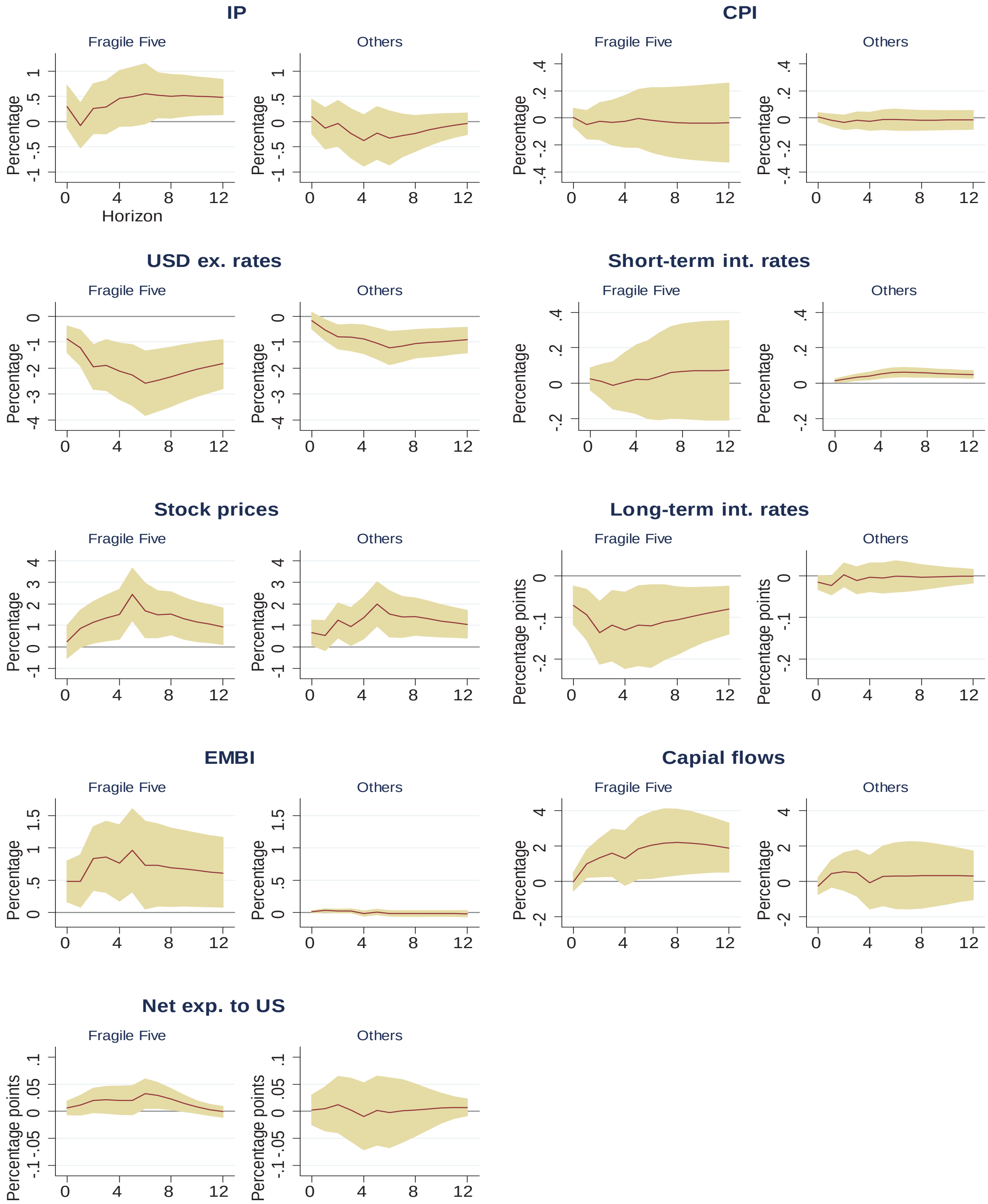


Figure 19: Impulse responses of the panel VAR on Fragile Five and others that includes the short term interest rate

Notes: Results are from a specification that uses the short-term interest rate instead of the monetary aggregate in the panel VAR. Subplots are arranged by variables and shown for two groups of countries: the fragile five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. See also the notes in Figure 9.

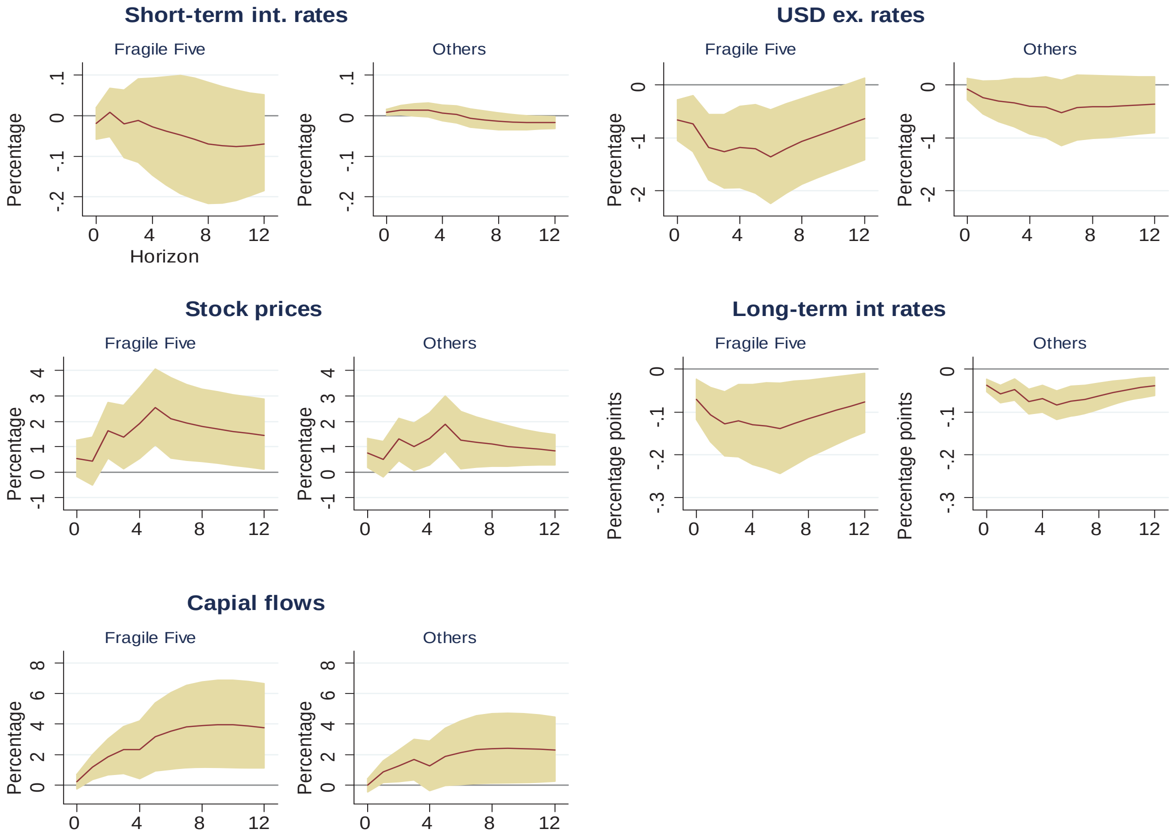


Figure 20: Impulse responses of the panel VAR with financial variables only on Fragile five and others that includes short term interest rate

Notes: Results are from a specification that uses the short-term interest rate instead of the monetary aggregate in the financial panel VAR. Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. See also the notes in Figure 10.

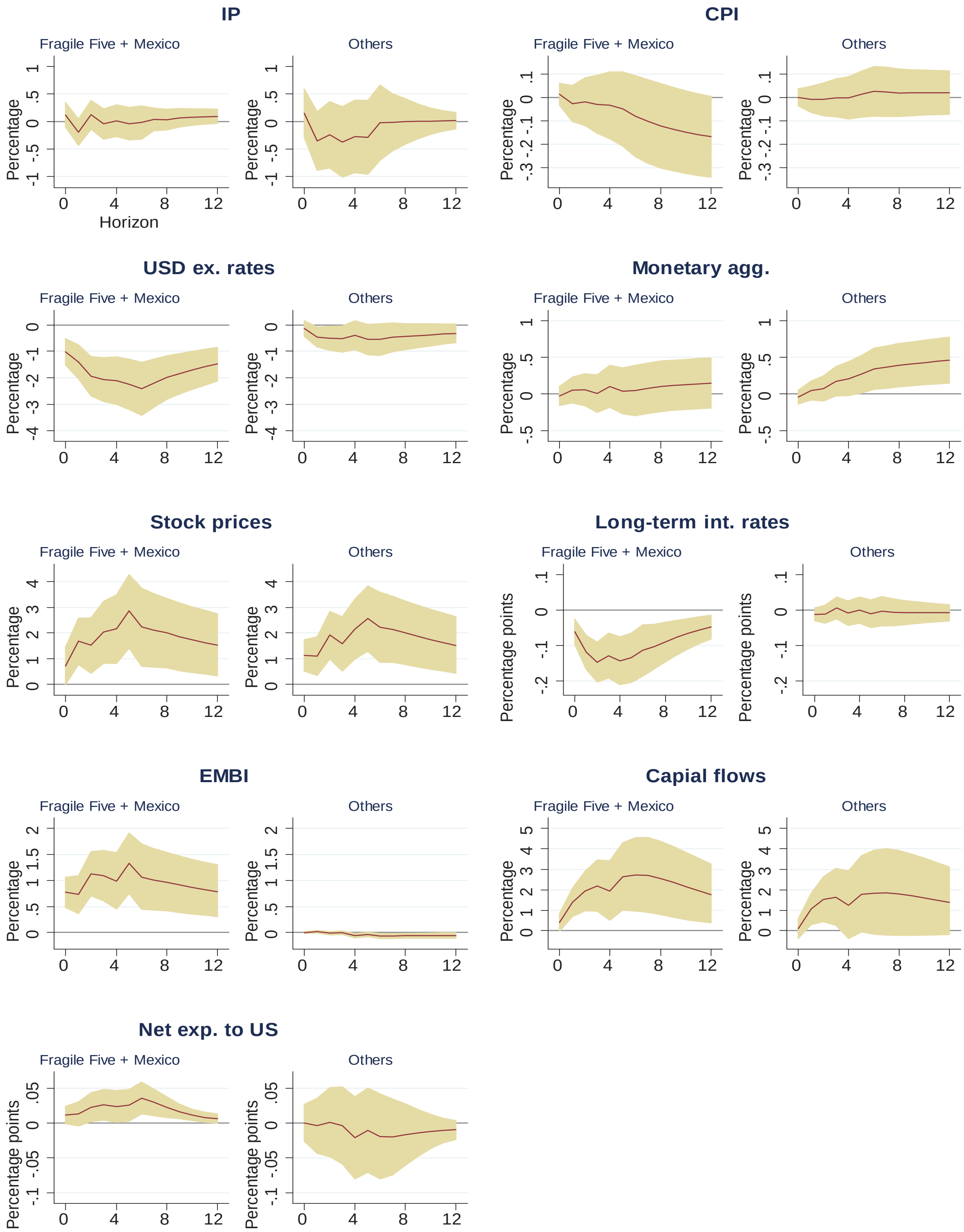


Figure 21: Impulse responses of the panel VAR on Fragile Five plus Mexico and others

Notes: Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries plus Mexico and the rest of emerging markets. See also the notes in Figure 7.

References

[1] Aizenman, Joshua, Mahir Binici, and Michael M. Hutchison (2014), "The Transmission of Federal Reserve Tapering News to Emerging Financial Markets," working paper.

[2] Ahmed, Shaghil, Brahima Coulibaly, and Andrei Zlate (2015), "International Financial Spillovers to Emerging Market Economies: How Important Are Economic Fundamentals?" working paper.

[3] Bauer, Michael D., and Glenn D. Rudebusch (2013), "The Signaling Channel for Federal Reserve Bond Purchases," working paper.

[4] Bauer, Michael D., and Christopher J. Neely (2014), "International Channels of the Fed's Unconventional Monetary Policy," *Journal of International Money and Finance*, 44, 24-46.

[5] Beraja, Martin, Andreas Fuster, Erik Hurst, and Joseph Vavra (2015), "Regional Heterogeneity and Monetary Policy," working paper.

[6] Bhattarai, Saroj, Gauti B. Eggertsson, and Bulat Gafarov (2015), "Time-Consistency and the Duration of Government Debt: A Signalling Theory of Quantitative Easing," working paper.

[7] Blanchard, Olivier, Jonathan D. Ostry, Atish R. Ghosh, and Marcos Chamon (2015), "Are Capital Inflows Expansionary or Contractionary? Theory, Policy Implications, and Some Evidence," working paper.

[8] Bowman, David, Juan M. Londono, and Horacio Sapriza (2014), "U.S. Unconventional Monetary Policy and Transmission to Emerging Market Economies," working paper.

[9] Bruno, Valentina, and Hyun Song Shin (2015), "Capital Flows and the Risk-taking Channel of Monetary Policy," *Journal of Monetary Economics*, 71, 119-132.

[10] Canova, Fabio (2005), "The Transmission of US Shocks to Latin America," *Journal of Applied Econometrics,* 20, 229-251.

[11] Canova, Fabio (2007), *Methods for Applied Macroeconomic Research*, Princeton, NJ: Princeton University Press.

[12] Canova, Fabio, and Matteo Ciccarelli (2013), "Panel Vector Autoregressive Models: A Survey," working paper.

[13] Cesa-Bianchi, Ambrogio, Luis, Cespedes, and Alessandro, Rebucci (2015), "Global Liquidity, House Prices and the Macroeconomy: Evidence from Advanced and Emerging Economies," *Journal of Money, Credit, and Banking*, 47, 301-335.

[14] Christiane Baumeister, and Luca Benati (2013), "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound," *International Journal of Central Banking*, 9, 165-212.

[15] Chen, Han, Vasco Curdia, and Andrea Ferrero (2012), "The Macroeconomic Effects of Large-scale Asset Purchase Programmes," *Economic Journal,* 122, 289-315.

[16] Chen, Qianying, Andrew Filardo, Dong He, and Feng Zhu (2014), "International Spillovers of Central Bank Balance Sheet Policies," working paper.

[17] Clarida, Richard, Jordi Gali, and Mark Gertler (2002), "A Simple Framework for International Monetary Policy Analysis," *Journal of Monetary Economics*, 49, 879-904.

[18] Corsetti, Giancarlo, and Paolo Pesenti (2005), "International Dimensions of Optimal Monetary Policy," *Journal of Monetary Economics*, 52, 281-305.

[19] Cushman, David O., and Tao Zha (1997), "Identifying Monetary Policy in a Small Open Economy Under Flexible Exchange Rates," *Journal of Monetary Economics*, 39, 433-448.

[20] Dahlhaus, Tatjana, and Garima Vasishtha (2014), "The Impact of U.S. Monetary Policy Normalization on Capital Flows to Emerging-Market Economies," working paper.

[21] D'Amico, Stefania, and Thomas B. King (2013), "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, 108, 425-448.

[22] Eichengreeen, Barry, and Poonam Gupta (2014), "Tapering Talk: The Impact of Expectations of Reduced Federal Reserve Purchases on Emerging Markets," working paper.

[23] Fawley, Brett W., and Christopher J. Neely (2013), "Four Stories of Quantitative Easing," *Federal Reserve Bank of St. Louis Review,* Jan/Feb, 51-88.

[24] Fratzscher, Marcel, Maro Lo Duca, and Roland Straub (2012), "A Global Monetary Tsunami? On the Spillovers of US Quantitative Easing," working paper.

[25] Gagnon, Joseph, Matthew Raskin, Julie Ramache, and Brian Sack (2011), "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases," *International Journal of Central Banking,* 7, 3-43.

[26] Gertler, Mark, and Peter Karadi (2011), "A Model of Unconventional Monetary Policy," *Journal of Monetary Economics*, 58, 17-34.

[27] Glick, Reuven, and Sylvain Leduc (2012), "Central Bank Announcements of Asset Purchases and the Impact on Global Financial and Commodity Markets," *Journal of International Money and Finance,* 31, 2078–2101.

[28] Glick, Reuven, and Sylvain Leduc (2013), "The Effects of Unconventional and Conventional U.S. Monetary Policy on the Dollar," working paper.

[29] Hamilton, James D., and Cynthia Wu (2012), "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment," *Journal of Money, Credit, and Banking,* 44, 3-46.

[30] Kim, Soyoung (2001), "International Transmission of U.S. Monetary Policy Shocks: Evidence from VAR's," *Journal of Monetary Economics,* 48, 339-372.

[31] Krishnamurthy, Arvind, and Annette Vissing-Jorgensen (2011), "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," *Brookings Papers on Economic Activity,* 43, 215-287.

[32] Lavigne, Robert, Subrata Sarker, and Garima Vasishtha (2014), "Spillover Effects of Quantitative Easing on Emerging Market Economies," *Bank of Canada Review,* Autumn, 23-33.

[33] Leeper, Eric M., Christopher A. Sims, and Tao Zha (1996), "What Does Monetary Policy Do?" *Brookings Papers on Economic Activity,* 2, 1-78.

[34] Lim, Jamus Jerome, Sanket Mohapatra, and Marc Stoker (2014),"Tinker, Taper, QE, Bye? The Effect of Quantitative Easing on Financial Flows to Developing Countries," working paper.

[35] Litterman, Robert (1986), "Forecasting With Bayesian Vector Autoregressions-Five Years of Experience," *Journal of Business & Economic Statistics,* 4, 25-38.

[36] Mackowiak, Bartosz (2007), "External Shocks, U.S. Monetary Policy and Macroeconomic Fluctuations in Emerging Markets," *Journal of Monetary Economics,* 54, 2512-2520.

[37] Meaning, Jack, and Feng Zhu (2011), "The Impact of Recent Central Bank Asset Purchase Programmes," *BIS Quarterly Review*, Dec, 73-83.

[38] Mishra, Prachi, Kenji Moriyama, Papa N'Diaye, and Lam Nguyen (2014), "Impact of Fed Tapering Announcements on Emerging Markets," working paper.

[39] Neely, Christopher J. (2010), "The Large-Scale Asset Purchases Had Large International Effects," working paper.

[40] Plummer, Martyn, Nicky Best, Kate Cowles, and Karen Vines (2006), "CODA: Convergence Diagnosis and Output Analysis for MCMC", *R News*, 6, 7-11.

[41] Rey, Helene (2013), "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence," *Proceedings of the Jackson Hole Economic Policy Symposium.*

[42] Rogers, John H., Chiara Scotti, and Jonathan H. Wright (2014), "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Cross-Country Comparison," working paper.

[43] Sims, Christopher A., and Tao Zha (1998), "Bayesian Methods for Dynamic Multivariate Models," *International Economic Review* 39, 949-968.

[44] Sims, Christopher A., and Tao Zha (2006a), "Does Monetary Policy Generate Recessions?" *Macroeconomic Dynamics,* 10*,* 231-272*.*

[45] Sims, Christopher A., and Tao Zha (2006b), “Were There Regime Switches in U.S. Monetary Policy?” *American Economic Review,* 96*, 54-81.*

[46] Tillmann, Peter (2014), “Unconventional Monetary Policy Shocks and the Spillovers to Emerging Markets,” working paper.

[47] Waggoner, Daniel F., and Tao Zha (2003a), “A Gibbs Sampler for Structural Vector Autoregressions,” *Journal of Economic Dynamics and Control*, 28, 349–366.

[48] Waggoner, Daniel F., and Tao Zha (2003b), “Likelihood Preserving Normalization in Multiple Equation Models,” *Journal of Econometrics*, 114, 329–347.

[49] Williamson, Steve (2012), “Scare Collateral, the Term Premium, and Quantitative Easing,” working paper.

[50] Wright, Jonathan (2012), “What does Monetary Policy do to Long-term Interest Rates at the Zero Lower Bound?” *Economic Journal*, 122, F447-F466.

Appendices

A Data description and sources

See the online data appendix for the complete list of the data with detailed descriptions and their sources. It also explains how quarterly GDP series are interpolated to monthly series for the US and the emerging market countries. For the latter countries, monthly GDP is used to normalize net exports to the US.

B Econometric methodology

B.1 Structural VAR for the US

As the methods for the Bayesian structural VAR are well described in Sims and Zha (1998), Waggoner and Zha (2003a; 2003b) and Sims and Zha (2006b), we refer readers to these papers for details of estimation methods. Here we only explain the hyperparameters for the Minesota-type prior distribution of the US VAR proposed by Sims and Zha (1998).

The Minnesota-type prior distribution is implemented by three types of dummy observations and there are six hyperparameters. The first type of the dummy observations expresses a prior belief that the dynamics of each variable in the US VAR is centered around a random walk behavior and has four hyperparameters μ_0, μ_1, μ_2, and μ_3. Hyperparameter μ_0 determines the overall tightness of prior beliefs, μ_1 the tightness of prior beliefs around a random walk process, and μ_3 the rate at which the prior variance shrinks as the lag order increases.[58] The second and third type of the dummy observations expresses a prior belief that each variable is likely to contain a unit root and a prior belief that the endogenous variables are likely to be cointegrated, respectively. The tightness of these two types of the dummy observations are determined by μ_4 and μ_5, respectively. As we use the monthly data, we set $\mu_0 = 0.6$, $\mu_1 = 0.1$, $\mu_3 = 1.2$, $\mu_4 = 5$ and $\mu_5 = 5$ in the baseline specification following Sims and Zha (2006b).

B.1.1 Posterior simulation

We use the Matlab code made public by Tao Zha to do Gibbs sampling from the posterior distribution of the US VAR: 60,000 draws are made, but the first 10,000 draws are discarded and the last 50,000 draws are used to make posterior inferences.

B.2 Panel VAR for the emerging market countries

We start with a description for the baseline case where we include all emerging market economies together. We then proceed to describing the method when we do estimation across two sub-groups of countries.

[58] Another hyperparameter, μ_2, is always set to 1 to keep the simultaneous equation framework in Sims and Zha (1998) contrary to the original equation-by-equation approach by Litterman (1986).

B.2.1 A case with a single group

Suppose that there are N countries indexed by i. We have an $m_z \times 1$ vector of endogenous variables $z_{i,t}$ for country i and an $m_x \times 1$ vector of exogenous variables x_t that can include a constant, a time trend or other exogenous variables and are common across countries. The sample covers the period from $t = 1, \cdots, T$. We condition the inference on initial p observations for $t = 0, -1, \cdots, -(p-1)$.

The dynamics of endogenous variables for country i can be written as

$$z_{i,t}^o = \sum_{j=1}^{p} B_{i,j} z_{i,t-j}^o + \sum_{j=0}^{q} D_{i,j} \varepsilon_{QE,t-j} + C_i x_{i,t}^o + u_{i,t}^o, \tag{B.1}$$

where $B_{i,j}$ for $j = 1, \cdots, p$ is $m_z \times m_z$, $D_{i,j}$ for $j = 1, \cdots, p$ is $m_z \times 1$, C_i is $m_z \times m_x$, and $u_{i,t}^o$ is $m_z \times 1$. The superscript o means that the variables are observables and the disturbance term is one for observable variables. Later we augment the sample with dummy observations with superscript d. Let us collect the regressors on the right hand side of (B.1) in $w_{i,t}^o$ as

$$w_{i,t}^o = \begin{bmatrix} z_{i,t-1}^{o\prime} & \cdots & z_{i,t-p}^{o\prime} & \varepsilon_{QE,t-0} & \cdots & \varepsilon_{QE,t-q} & x_{i,t}^{o\prime} \end{bmatrix}',$$

and write (B.1) as

$$z_{i,t}^{o\prime} = w_{i,t}^{o\prime} \Gamma_i + u_{i,t}^{o\prime}, \tag{B.2}$$

where Γ_i collects the coefficient matrices on the right hand side of (B.1)

$$\Gamma_i = \begin{bmatrix} B_{i,1} & \cdots & B_{i,p} & D_{i,0} & \cdots & D_{i,q} & C_i \end{bmatrix}'.$$

Note that $w_{i,t}^o$ is an $m_w \times 1$ vector with $m_w = m_z p + (q+1) + m_x$ and Γ_i is an $m_w \times m_z$ matrix. Now vectorize equation (B.2) as

$$z_{i,t}^o = \left(I_{m_z} \otimes w_{i,t}^{o\prime}\right) \gamma_i + u_{i,t}^o, \tag{B.3}$$

where $\gamma_i = \mathrm{vec}\left(\Gamma_i\right)$, and stack (B.3) for $i = 1, \cdots, N$ as

$$\boldsymbol{z}_t^o = \boldsymbol{W}_t^o \boldsymbol{\gamma} + \boldsymbol{u}_t^o, \tag{B.4}$$

where

$$\boldsymbol{z}_t^o = \begin{bmatrix} z_{1,t}^o \\ \vdots \\ z_{N,t}^o \end{bmatrix}, \; \boldsymbol{W}_t^o = \begin{bmatrix} \left(I_{m_z} \otimes w_{1,t}^{o\prime}\right) & & 0 \\ & \ddots & \\ 0 & & \left(I_{m_z} \otimes w_{N,t}^{o\prime}\right) \end{bmatrix}, \; \boldsymbol{\gamma} = \begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_N \end{bmatrix}, \text{ and } \boldsymbol{u}_t^o = \begin{bmatrix} u_{1,t}^o \\ \vdots \\ u_{N,t}^o \end{bmatrix}.$$

Note that $\boldsymbol{z}_t^o$ is $N m_z \times 1$, W_t^o is $N m_z \times N m_z m_w$, $\boldsymbol{\gamma}$ is $N m_w m_z \times 1$ and $\boldsymbol{u}_t^o$ is $N m_z \times 1$. It is assumed that $\boldsymbol{u}_t^o \sim \mathbb{N}\left(\boldsymbol{0}, \boldsymbol{\Sigma}\right)$ with $\boldsymbol{\Sigma}$ being $N m_z \times N m_z$ and positive definite. Let $m_\gamma = m_w m_z$ and $m_{\gamma N} = N m_\gamma$.

Prior and posterior distribution of $\boldsymbol{\gamma}$ (γ_i's) and $\boldsymbol{\Sigma}$ We describe the prior and posterior distributions of $\boldsymbol{\gamma}$ (γ_i's) ad $\boldsymbol{\Sigma}$ next.

Prior distribution We take the random coefficient approach as discussed in the main text: γ_i is given as

$$\gamma_i = \bar{\gamma} + v_i, \tag{B.5}$$

for $i = 1, \cdots, N$, where $\bar{\gamma}$ is an $m_\gamma \times 1$ vector and $v_i \sim \mathbb{N}\left(0, \Sigma_i \otimes \underline{\Sigma}_i\right)$. Note that Σ_i is an $m_z \times m_z$ matrix that is the i-th block on the diagonal of $\boldsymbol{\Sigma}$ and $\underline{\Sigma}_i$ is an $m_w \times m_w$ positive definite matrix. Equation (B.5) can be written as

$$\gamma_i | \bar{\gamma}, \boldsymbol{\Sigma} \sim \mathbb{N}\left(\bar{\gamma}, \Sigma_i \otimes \underline{\Sigma}_i\right).$$

We assume that γ_i's are independent of each other conditional on $\bar{\gamma}$ and $\boldsymbol{\Sigma}$. That is, $E\left(v_i v_j'\right) = 0$ for $i \neq j$. The prior distribution for $\bar{\gamma}$ is described below. We set $\underline{\Sigma}_i = 5 \times I_{m_w}$.

The prior distribution for $\boldsymbol{\Sigma}$ is inverted-Wishart, or alternatively, the prior distribution for $\boldsymbol{\Sigma}^{-1}$ is Wishart as

$$\boldsymbol{\Sigma}^{-1} \sim \mathbb{W}\left(\underline{\nu}, \underline{S}^{-1}\right),$$

where $\underline{\nu} > N m_z + 1$ and $\underline{S}$ is $N m_z \times N m_z$ and positive definite. We set $\bar{\nu} = N m_z + 2$ that leads to a loose prior on $\boldsymbol{\Sigma}^{-1}$. For $\underline{S}$, ideally we would use a training sample to get the estimate of the variance matrix of residuals from a VAR model. However, because of the small size of our sample and the fact that it falls on the normal times immediately before our sample, we do not use such a training sample. We take a practical approach and use the estimated variance matrix of OLS residuals from an individual VAR model with the same specification for each country.

Posterior distribution We derive the posterior distribution of $\boldsymbol{\gamma}$ (γ_i's) conditional on $\boldsymbol{\Sigma}$ and $\bar{\gamma}$ and the posterior distribution of $\boldsymbol{\Sigma}$ conditional on $\boldsymbol{\gamma}$ and $\bar{\gamma}$. Let

$$\tilde{\boldsymbol{\gamma}} = \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{W}_t^{o} + \underline{\boldsymbol{\Sigma}}_\gamma^{-1}\right)^{-1} \left[\left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{W}_t^{o}\right) \hat{\boldsymbol{\gamma}} + \left(\underline{\boldsymbol{\Sigma}}_\gamma^{-1}\right) \bar{\boldsymbol{\gamma}}\right],$$

where $\bar{\boldsymbol{\gamma}} = 1_N \otimes \bar{\gamma}$ with 1_N being an $N \times 1$ vector of 1's,

$$\hat{\boldsymbol{\gamma}} = \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{W}_t^{o}\right)^{-1} \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{z}_t^{o}\right),$$

and

$$\underline{\boldsymbol{\Sigma}}_\gamma = \begin{bmatrix} \Sigma_1 \otimes \underline{\Sigma}_1 & & 0 \\ & \ddots & \\ 0 & & \Sigma_N \otimes \underline{\Sigma}_N \end{bmatrix}.$$

It follows that

$$\boldsymbol{\gamma}|\bar{\gamma}, \boldsymbol{\Sigma}, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{N}\left[\tilde{\boldsymbol{\gamma}}, \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime}\boldsymbol{\Sigma}^{-1}\boldsymbol{W}_t^o + \underline{\boldsymbol{\Sigma}}_{\gamma}^{-1}\right)^{-1}\right], \tag{B.6}$$

and

$$\boldsymbol{\Sigma^{-1}}|\boldsymbol{\gamma}, \bar{\gamma}, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{W}\left(T + \underline{\nu}, \tilde{S}^{-1}\right), \tag{B.7}$$

where

$$\tilde{S} = \sum_{t=1}^{T} (\boldsymbol{z}_t^o - \boldsymbol{W}_t^o\boldsymbol{\gamma})(\boldsymbol{z}_t^o - \boldsymbol{W}_t^o\boldsymbol{\gamma})' + \underline{S}.$$

Prior and posterior distribution for $\bar{\gamma}$ We now describe the prior and posterior distributions of $\bar{\gamma}$. It is assumed that before observing the data,

$$\bar{\gamma} \sim \mathbb{N}\left(\bar{\hat{\gamma}}, \underline{\Sigma}_{\bar{\gamma}}\right),$$

where $\bar{\hat{\gamma}}$ is the mean of the vectorized OLS estimator of γ_i's on the augmented data matrix that includes the actual data for country i and the dummy observations

$$\bar{\hat{\gamma}} = \frac{1}{N}\sum_{i=1}^{N} \hat{\gamma}_i^{o+d},$$

and

$$\underline{\Sigma}_{\bar{\gamma}} = s_{\bar{\gamma}} I_{m_\gamma}.$$

The factor $s_{\bar{\gamma}}$ controls the tightness of the prior distribution for $\bar{\gamma}$ and is set to 0.005.

Dummy observations in the data matrix are in the spirit of the Minnesota prior and as implemented in the code `rfvar3` written by Chris Sims. Therefore, the prior distribution for $\bar{\gamma}$ is in fact a mixture of three different prior distributions after some adjustment: a normal distribution centered around the mean of the OLS estimates of VARs for individual entities and two dummy observations prior distributions. Again, because of the small size of our sample, we take a practical approach and use the OLS estimates from an individual VAR model with the same specification for each country to guide the posterior distribution.

Specifically, we include the following two types of dummy observations. The first type represents a prior belief that there exists co-persistence among endogenous variables. Let $\bar{z}_{i,0}^o = p^{-1}\sum_{j=1}^{p} z_{i,1-j}^o$ and $\bar{x}_0 = p^{-1}\sum_{j=1}^{p} x_{1-j}$ which are the sample mean of the initial observations for country i and the common exogenous variables. Then we include in the data matrix an observation $\left\{\lambda \boldsymbol{z}_1^d, \lambda \boldsymbol{W}_1^d\right\}$

where $\boldsymbol{z}_1^d = \left[\begin{array}{ccc} \bar{z}_{1,0}^{o\prime} & \cdots & \bar{z}_{N,0}^{o\prime} \end{array} \right]'$, and

$$\boldsymbol{W}_1^d = \left[\begin{array}{ccc} \left(I_{m_z} \otimes w_{1,1}^{d\prime}\right) & & 0 \\ & \ddots & \\ 0 & & \left(I_{m_z} \otimes w_{N,1}^{d\prime}\right) \end{array} \right],$$

with $w_{i,1}^d = \left[\begin{array}{cccccccc} \bar{z}_{i,0}^{o\prime} & \cdots & \bar{z}_{i,0}^{o\prime} & 0 & \cdots & 0 & \bar{x}_0^{o\prime} \end{array} \right]'$ for $i = 1, 2, \cdots, N$. When it is substituted in (B.4), it would imply

$$\lambda \boldsymbol{z}_1^d = \lambda \boldsymbol{W}_1^d \boldsymbol{\gamma} + \boldsymbol{u}_1^d.$$

The hyperparameter λ controls how the tightness of the first type of dummy observations.

The second type of dummy observations represents a prior belief in favor of own-persistence of endogenous variables. Let $\bar{Z}_{i,0}^o$ denote an $m_z \times m_z$ symmetric diagonal matrix with $\bar{z}_{i,0}$ on the diagonal and zeros off the diagonal. We include, in the data matrix, m_z observations $\left\{\mu \boldsymbol{z}_t^d, \mu \boldsymbol{W}_t^d\right\}_{t=2}^{m_z+1}$ such that

$$\left(\begin{array}{c} \boldsymbol{z}_2^d \\ \vdots \\ \boldsymbol{z}_{m_z+1}^d \end{array} \right) = \text{vec} \left(\begin{array}{c} \bar{Z}_{1,0}^o \\ \vdots \\ Z_{N,0}^o \end{array} \right),$$

and

$$\boldsymbol{W}_t^d = \left[\begin{array}{ccc} \left(I_{m_z} \otimes w_{1,t}^{d\prime}\right) & & 0 \\ & \ddots & \\ 0 & & \left(I_{m_z} \otimes w_{N,t}^{d\prime}\right) \end{array} \right],$$

for $t = 2, \cdots, m_z + 1$ where $w_{i,t}^d = \left[\begin{array}{ccccccc} \left(\bar{z}_{i,0}^o\right)_{(t-1)}' & \cdots & \left(\bar{z}_{i,0}^o\right)_{(t-1)}' & 0 & \cdots & 0 & 0_{m_x \times 1}' \end{array} \right]'$ for $i = 1, 2, \cdots, N$ and $\left(\bar{z}_{i,0}^o\right)_{(t-1)}$ is an $m_z \times 1$ vector of zeros except that the $(t-1)$-th element is equal to the $(t-1)$-th element of $\bar{z}_{i,0}^o$. The second type implies that the j-th equation of the i-th unit implies that there is a unit root for the j-th variable of $z_{i,t}$. Note that the exogenous variables are assumed to take on zeros. The hyperparameter μ controls the tightness of the second type of dummy observations.

We set $\lambda = 5$ and $\mu = 2$ as is recommended in the literature. It follows that

$$\bar{\gamma} | \boldsymbol{\gamma}, \boldsymbol{\Sigma}, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{N} \left[\bar{\bar{\gamma}}, \left(\sum_{i=1}^N \left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} + \underline{\Sigma}_{\bar{\gamma}}^{-1} \right)^{-1} \right], \tag{B.8}$$

where

$$\bar{\bar{\gamma}} = \left(\sum_{i=1}^N \left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} + \underline{\Sigma}_{\bar{\gamma}}^{-1} \right)^{-1} \left(\sum_{i=1}^N \left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} \gamma_i + \underline{\Sigma}_{\bar{\gamma}}^{-1} \bar{\bar{\gamma}} \right).$$

Posterior simulation We use the Gibbs sampler to alternatingly draw $\boldsymbol{\gamma}$ conditional on $\boldsymbol{\Sigma}$ and $\bar{\gamma}$ from (B.6), $\boldsymbol{\Sigma}$ conditional on $\boldsymbol{\gamma}$ and $\bar{\gamma}$ from (B.7), and $\bar{\gamma}$ conditional on $\boldsymbol{\gamma}$ and $\boldsymbol{\Sigma}$ from (B.8). We make 200,000 draws and use only the last 100,000 draws to make posterior inferences.

B.2.2 A case with two groups

Now we consider a case where there are two groups with different average effects. Without loss of generality, the first group consistent of countries $i = 1, \cdots, N_1$ and the second group consists of countries $i = N_1 + 1, \cdots, N$. We reuse some notations from the previous section. But their meaning should be clear from the context.

We assume that for $i = 1, \cdots, N$

$$\gamma_i = \bar{\gamma}_1 \times I_F(i) + \bar{\gamma}_2 \times [1 - I_F(i)] + v_i,$$

where $I_F(i)$ is an indicator function that takes on 1 if country i belongs to the first group and 0 otherwise, $v_i \sim \mathbb{N}(0, \Sigma_i \otimes \underline{\Sigma}_i)$. Independence between α_i's is assumed within each group and across groups: $E\left(v_i v_j'\right) = 0$ for $i \neq j$.

Prior and posterior distribution for $\boldsymbol{\gamma}$ (γ_i's) and $\boldsymbol{\Sigma}$ We use the same hyperparameters for the prior distribution of $\boldsymbol{\gamma}$ and $\boldsymbol{\Sigma}$ as in the single group case. It follows that

$$\boldsymbol{\gamma}|\bar{\gamma}_1, \bar{\gamma}_2, \boldsymbol{\Sigma}, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{N}\left[\tilde{\boldsymbol{\gamma}}, \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{W}_t^o + \underline{\boldsymbol{\Sigma}}_\gamma^{-1}\right)^{-1}\right], \tag{B.9}$$

where

$$\begin{aligned}
\bar{\boldsymbol{\gamma}} &= \begin{pmatrix} I_F(1) & \cdots & I_F(N) \end{pmatrix}' \otimes \bar{\gamma}_1 + \begin{pmatrix} 1 - I_F(1) & \cdots & 1 - I_F(N) \end{pmatrix}' \otimes \bar{\gamma}_2, \\
\hat{\boldsymbol{\gamma}} &= \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{W}_t^o\right)^{-1} \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{z}_t^o\right), \\
\tilde{\boldsymbol{\gamma}} &= \left(\sum_{t=1}^{T} \boldsymbol{W}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{W}_t^o + \underline{\boldsymbol{\Sigma}}_\gamma^{-1}\right)^{-1} \left[\left(\sum_{t=1}^{T} \boldsymbol{X}_t^{o\prime} \boldsymbol{\Sigma}^{-1} \boldsymbol{X}_t^o\right) \hat{\boldsymbol{\gamma}} + \left(\underline{\Sigma}_\gamma^{-1}\right) \bar{\boldsymbol{\gamma}}\right],
\end{aligned}$$

and

$$\boldsymbol{\Sigma^{-1}}|\boldsymbol{\gamma}, \bar{\gamma}_1, \bar{\gamma}_2, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{W}\left(T + \underline{\nu}, \tilde{S}^{-1}\right), \tag{B.10}$$

where

$$\tilde{S} = \sum_{t=1}^{T} (\boldsymbol{z}_t^o - \boldsymbol{W}_t^o \boldsymbol{\gamma})(\boldsymbol{z}_t^o - \boldsymbol{W}_t^o \boldsymbol{\gamma})' + \underline{S}.$$

Prior and posterior distribution for $\bar{\gamma}_1$ and $\bar{\gamma}_2$ A priori, we assume that

$$\begin{aligned}\bar{\gamma}_1 &\sim \mathbb{N}\left(\bar{\bar{\gamma}}_1, \underline{\Sigma}_{\bar{\gamma}}\right),\\ \bar{\gamma}_2 &\sim \mathbb{N}\left(\bar{\bar{\gamma}}_2, \underline{\Sigma}_{\bar{\gamma}}\right),\end{aligned}$$

where $\bar{\bar{\gamma}}_1$ and $\bar{\bar{\gamma}}_2$ are the mean of the vectorized OLS estimator of γ_i's for the first and second group, respectively, on the augmented data matrix that includes the actual data for unit i and the dummy observations

$$\begin{aligned}\bar{\bar{\gamma}}_1 &= \frac{1}{N_1}\sum_{i=1}^{N_1}\hat{\gamma}_i^{o+d},\\ \bar{\bar{\gamma}}_2 &= \frac{1}{N-N_1}\sum_{i=N_1+1}^{N}\hat{\gamma}_i^{o+d}\end{aligned}$$

and

$$\underline{\Sigma}_{\bar{\gamma}} = s_{\bar{\gamma}} I_{m_\gamma}.$$

We use the same hyperparameters for the prior distribution of $\boldsymbol{\gamma}$ and $\boldsymbol{\Sigma}$ as in the single group case.

Conditional on $\boldsymbol{\gamma}$ and $\boldsymbol{\Sigma}$, the posterior distribution for $\bar{\gamma}_1$ is

$$\bar{\gamma}_1|\boldsymbol{\gamma}, \boldsymbol{\Sigma}, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{N}\left[\tilde{\bar{\gamma}}_1, \left(\sum_{i=1}^{N_1}\left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} + \Sigma_{\bar{\gamma}}^{-1}\right)^{-1}\right], \tag{B.11}$$

and the posterior distribution for $\bar{\gamma}_2$ is

$$\bar{\gamma}_2|\boldsymbol{\gamma}, \boldsymbol{\Sigma}, \boldsymbol{z}_T^o, \cdots, \boldsymbol{z}_1^o, \boldsymbol{z}_0^o, \cdots, \boldsymbol{z}_{-p+1}^o \sim \mathbb{N}\left[\tilde{\bar{\gamma}}_2, \left(\sum_{i=N_1+1}^{N}\left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} + \Sigma_{\bar{\gamma}}^{-1}\right)^{-1}\right], \tag{B.12}$$

where

$$\begin{aligned}\tilde{\bar{\gamma}}_1 &= \left(\sum_{i=1}^{N_1}\left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} + \Sigma_{\bar{\gamma}}^{-1}\right)^{-1}\left[\left(\sum_{i=1}^{N_1}\left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1}\right)\gamma_i + \left(\Sigma_{\bar{\gamma}}^{-1}\right)\bar{\bar{\gamma}}_1\right],\\ \tilde{\bar{\gamma}}_2 &= \left(\sum_{i=N_1+1}^{N}\left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1} + \Sigma_{\bar{\gamma}}^{-1}\right)^{-1}\left[\left(\sum_{i=N_1+1}^{N}\left(\Sigma_i \otimes \underline{\Sigma}_i\right)^{-1}\right)\gamma_i + \left(\Sigma_{\bar{\gamma}}^{-1}\right)\bar{\bar{\gamma}}_2\right].\end{aligned}$$

Posterior simulation We use the Gibbs sampler to alternatingly draw $\boldsymbol{\gamma}$ conditional on $\boldsymbol{\Sigma}$, $\bar{\gamma}_1$ and $\bar{\gamma}_2$ from (B.9), $\boldsymbol{\Sigma}$ conditional on $\boldsymbol{\gamma}$, $\bar{\gamma}_1$ and $\bar{\gamma}_2$ from (B.10), and $\bar{\gamma}_1$ and $\bar{\gamma}_2$ conditional on $\boldsymbol{\gamma}$ and $\boldsymbol{\Sigma}$ from (B.11) and (B.12). We make 200,000 draws and use only the last 100,000 draws to make posterior inferences.

C Additional Results

Here we report some additional results related to extensions and robustness.

C.1 Domestic Effects of US QE Shock

We first provide additional results in the US VAR.

C.1.1 Extensions of QE period US VAR

We present results when we further extend the baseline US VAR to include additional variables related to economic and housing activity, where these variables enter the slow moving block. In Panels (a) and (b) of Figure 22, we show the responses of the baseline variables as well as a measures of aggregate consumption, Personal Consumption Expenditure and a measure of vehicle sales, in an extended six-variable VAR allowing for QE to affect both output and consumption. Consistent with a strong output effect we find in our baseline specification, both consumption measures respond significantly and positively to an expansionary QE shock. Our inference on the baseline variables is all robust and moreover, for these additional variables, the responses are in line with the rest of our results.

We also assess implications of QE on the housing market further in alternate, extended VAR specifications.[59] Here we include mortgage application and loan size (refinancing) in the slow-moving block and house prices as an asset price in the fast moving block. The results are presented in Panels (a) and (b) of Figure 23. Consistent with the literature (Beraja et al (2015)), we find that both mortgage application and loan size respond positively to expansionary QE shock. Also, consistent with them, we find that this significant impact is observed only for refinancing and not on purchase measures.[60] As is clear, our inference on the baseline variables is all robust and moreover, for these additional variables, the responses are in line with the current literature.

C.1.2 Conventional period US VAR

For completeness and further comparison, we now assess the importance of the identified US conventional monetary policy shock in explaining forecast error variance of the various variables at different horizons. This variance decomposition result is presented in Table 8. As documented by a large literature, the US monetary policy shock explains a non-trivial, but not predominant, amount of variation in output. Moreover, it explains very little of the variation in prices. For example, at the 6 and 12 month horizons, the monetary policy shock explains at most 22% of the variation in output and almost no variation in prices. Finally, it explains around of the variation for 90% of the variation in M2 and 3% of that in stock prices.

We now show the results based on a recursive identification for the conventional period. As we mentioned before, there are two possible ordering, based on whether Federal Funds rate is ordered

[59] The datasource for mortgage application and loan size is Datastream.

[60] To conserve space we do not show the non-significant results on purchase measures.

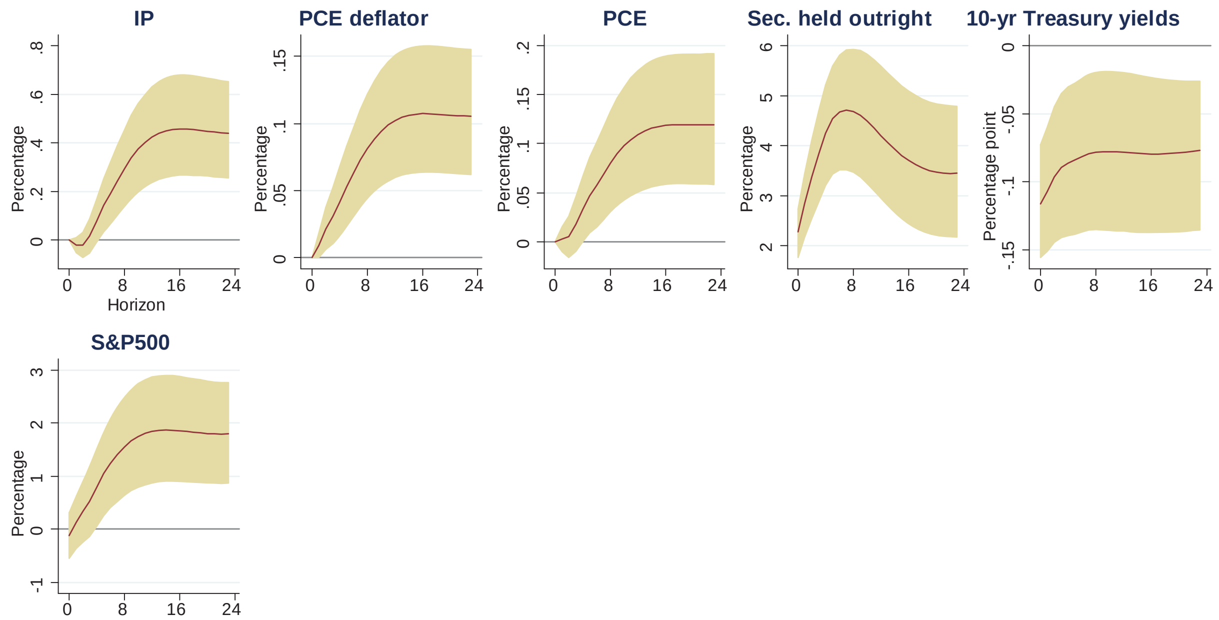
Table 8: Variance Decomposition

	Industrial production	PCE deflator	Federal funds rate	M2	S&P500 index
Impact	0.00	0.00	0.23	0.88	0.01
	[0.00, 0.00]	[0.00, 0.00]	[0.08, 0.37]	[0.78, 0.99]	[0.00, 0.01]
3 month	0.01	0.00	0.15	0.93	0.02
	[0.00, 0.01]	[0.00, 0.01]	[0.04, 0.26]	[0.89, 0.97]	[0.00, 0.05]
6 month	0.06	0.01	0.08	0.90	0.03
	[0.03, 0.10]	[0.00, 0.01]	[0.01, 0.15]	[0.86, 0.96]	[0.00, 0.05]
12 month	0.22	0.01	0.03	0.89	0.02
	[0.12, 0.31]	[0.00, 0.03]	[0.00, 0.06]	[0.83, 0.96]	[0.00, 0.04]

Notes: The table shows the contribution of the conventional monetary policy 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.

third or fourth. Panels (a) and (b) of Figure 24 show that while inference on output is similar across the recursive and non-recursive identification schemes, the recursive identification method leads to a response of prices that displays a prominent price puzzle. That is, following a contractionary monetary policy shock, while output decreases, prices increase significantly for several periods.

(a) Extension with PCE



(b) Extension with vehicle sales

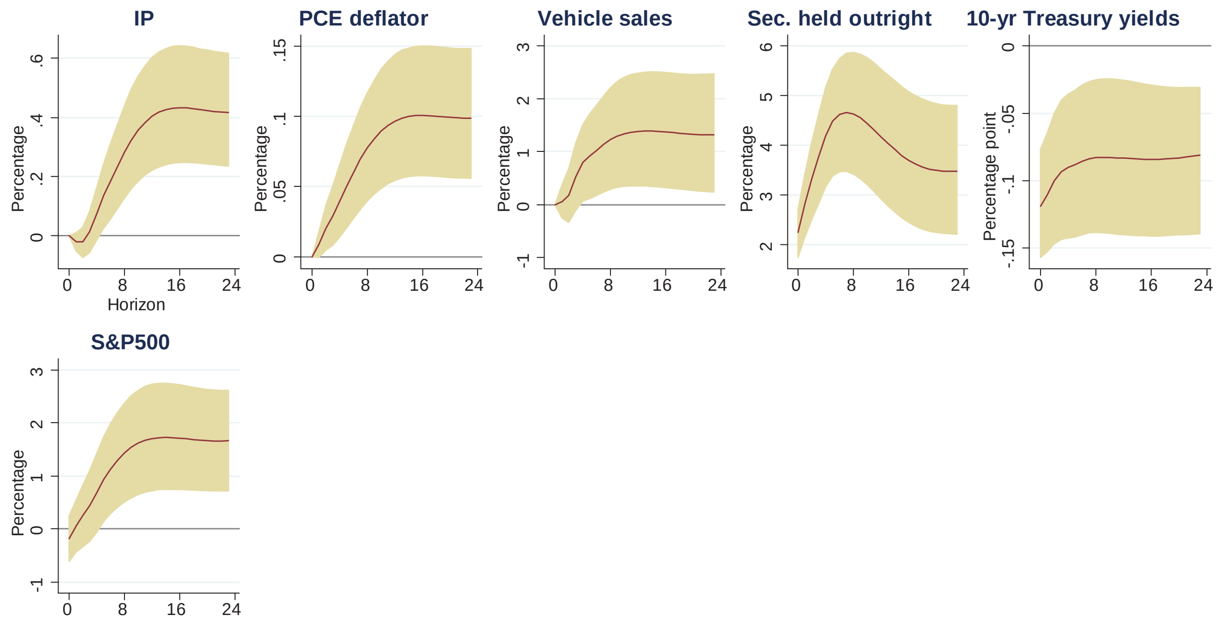
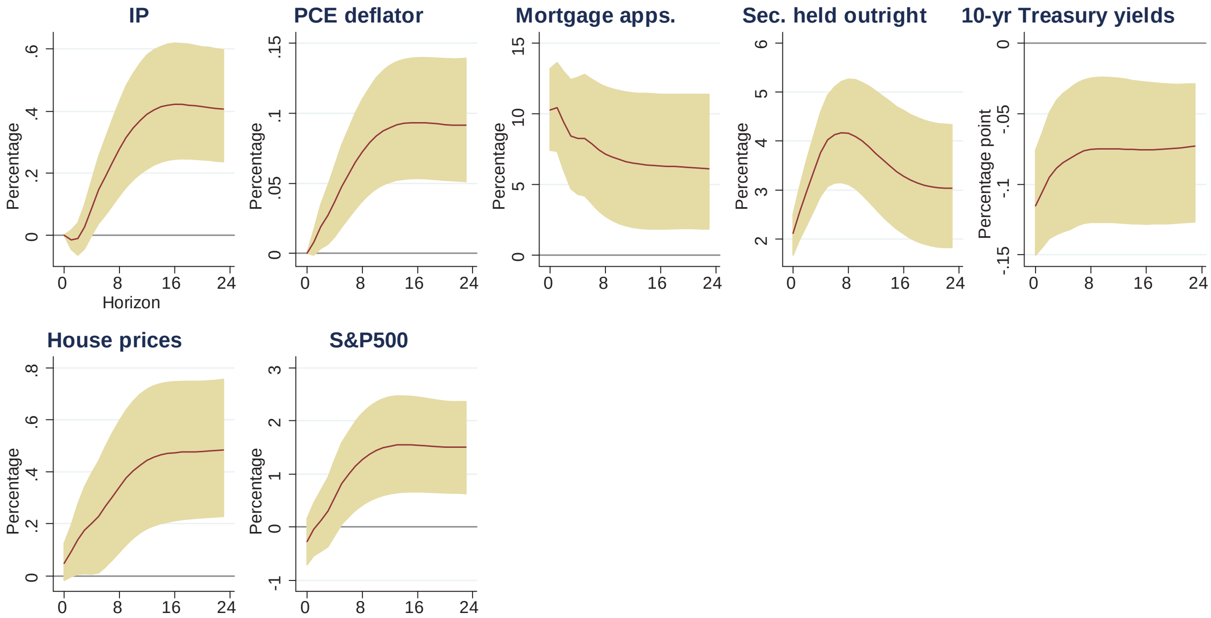


Figure 22: Impulse responses to the QE shock in an extended US VAR with consumption

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

(a) Extension with mortgage applications and house prices



(b) Extension with the loan size and house prices

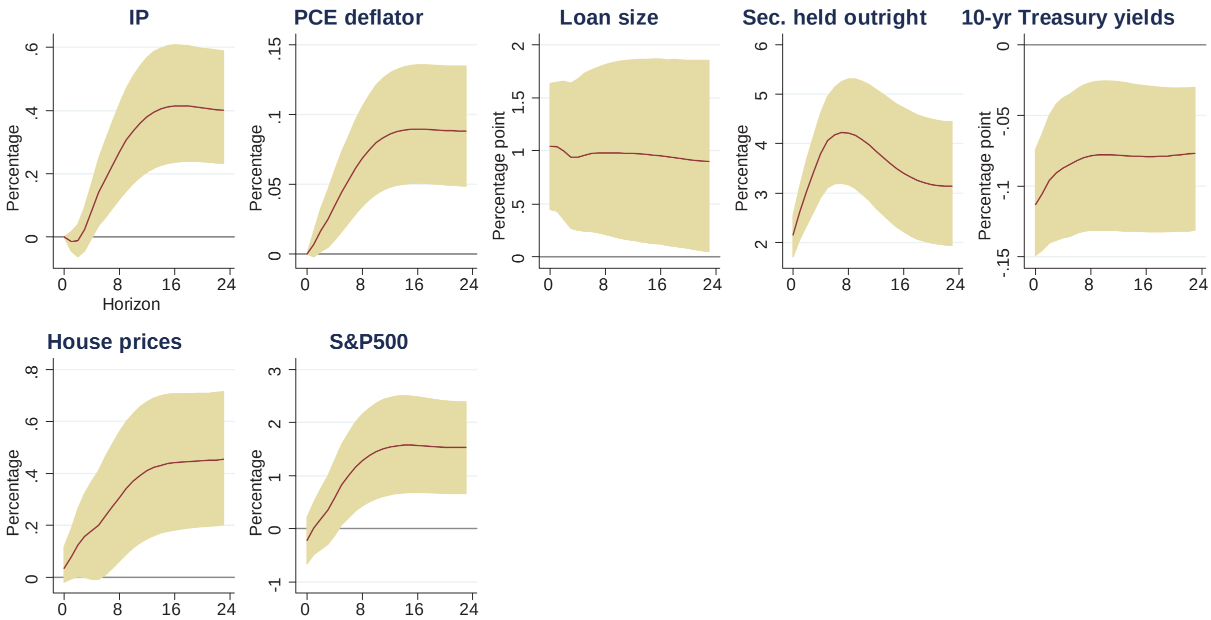
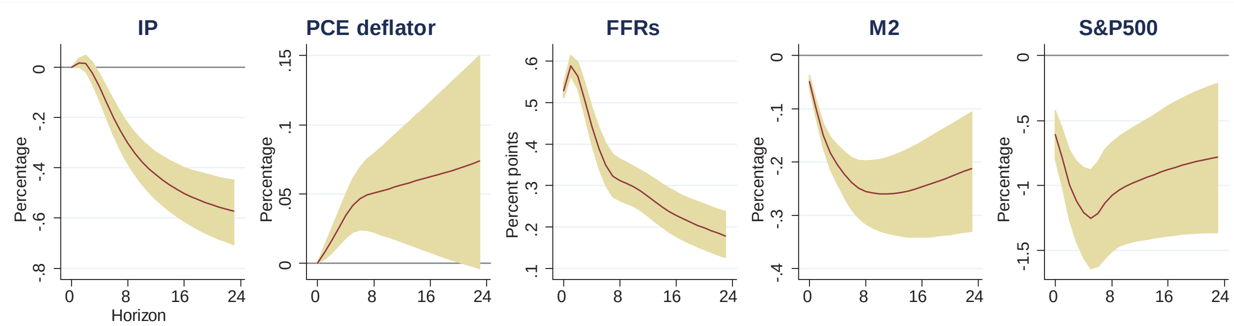


Figure 23: Impulse responses to the QE shock in an extended US VAR with housing activity and prices

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

(a) Recursive identification with FFRs before M2



(b) Recursive identification with FFRs after M2

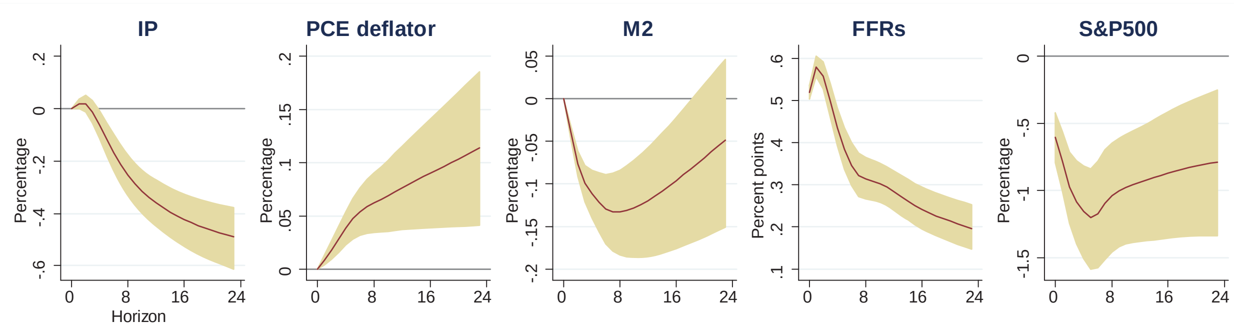


Figure 24: Impulse responses to the conventional monetary policy shock for the US VAR with recursive identification

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

C.2 Spillover Effects of US QE Shock

We now provide additional results in the Emerging markets panel VAR.

C.2.1 One lag

Since the Bayesian Information Criteria favored one lag for the endogenous variables, we now present results based on that specification of the panel VAR. Note that our baseline specification used three lags of the endogenous variables. Our results are robust to this variation in specification. To conserve space, here we only present results based on the sub-group estimation, where we consider Fragile Five as one group and the rest of emerging market economies as another. Figure 25 shows the results from the baseline VAR while Figure 26 presents results from the financial VAR. While the statistical precision changes slightly for some variables here compared to the baseline in Figures 9 and 10, on balance, the comparison suggests that our inference is robust on balance.

C.2.2 Controlling for announcement dates

Our approach in estimating the QE shock has relied on the size of the balance sheet, thereby focussing on realized/implementation effects of balance sheet policies, to extract a continuous measure of the shock. We now control for announcement dates that have also received considerable attention in the literature as around those dates there were significant movements in asset prices internationally. We capture these effects by using dummies in our baseline panel VAR for emerging markets for the following important QE dates that we highlighted before in the data section: March 2009 for QE1, Nov 2010 for QE2, Sept 2011 for MEP, Sept and Dec 2012 for QE3, and May 2013 for Taper scare.[61] In Figures 27 and 28 we present the results from this specification for the Fragile five and the rest of the countries, for the panel VAR that includes macroeconomic variables and the purely financial panel VAR respectively.[62] Overall, the results are robust and similar to our baseline estimation. From Figure 27, it is clear that except for some differences in the behavior of the long-term interest rate, with the response now less persistent (but still negative) for the Fragile Five countries and the response now also negative for the other countries, the results are even quantitatively comparable to the baseline results. Similarly, from Figure 28 it is clear that the results are qualitatively and quantitatively similar to the baseline results, with in fact stronger and more persistent effects on the exchange rate of the Fragile Five countries.

[61] Note that we do not have a Nov 2008 dummy as our panel VAR data effectively starts on 2009.

[62] To conserve space, we only present the results based on the sub-groups of countries here.

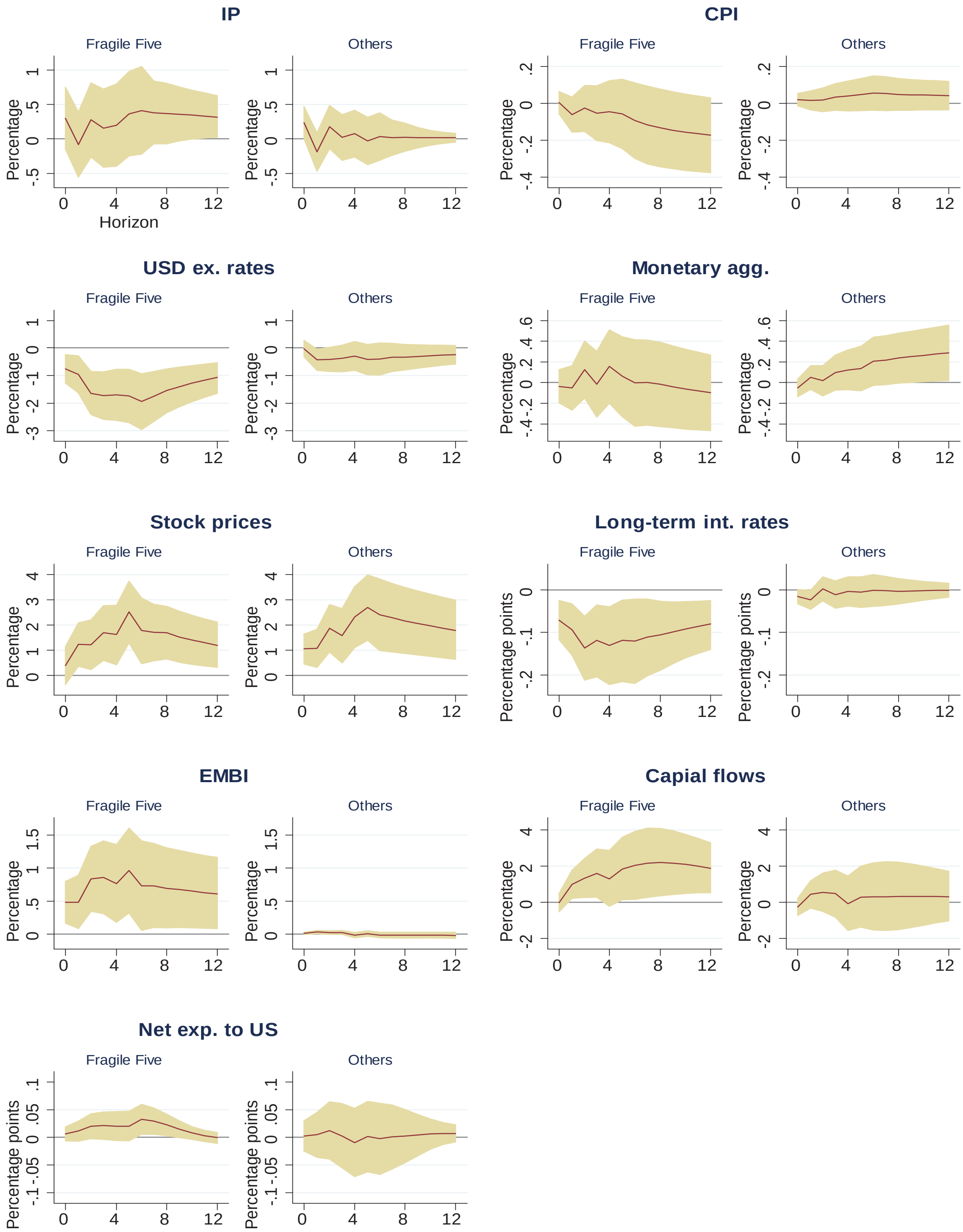


Figure 25: Impulse responses of the panel VAR with one lag on Fragile Five and others

Notes: Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. See the notes in Figure 7.

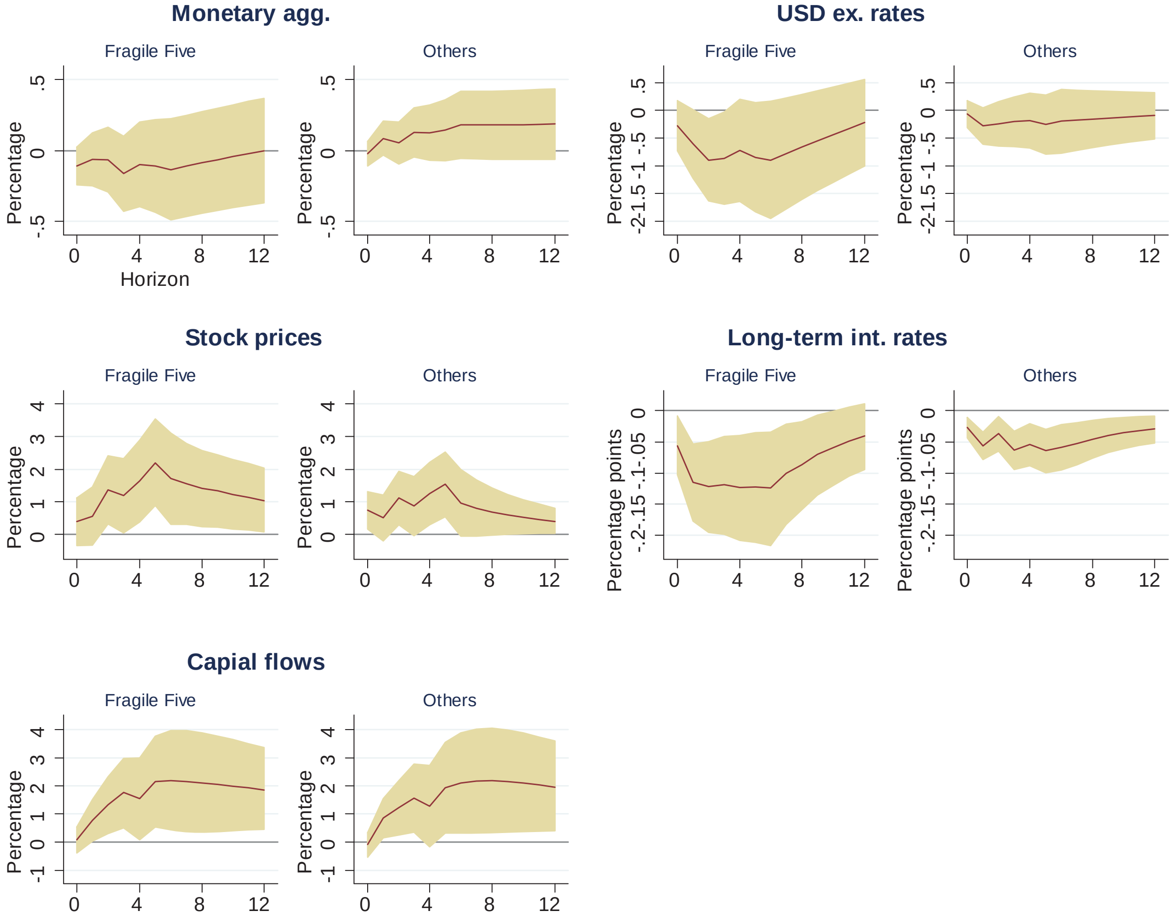


Figure 26: Impulse responses of the panel VAR with one lag on Fragile Five and others with only financial variables

Notes: Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. See the notes in Figure 7.

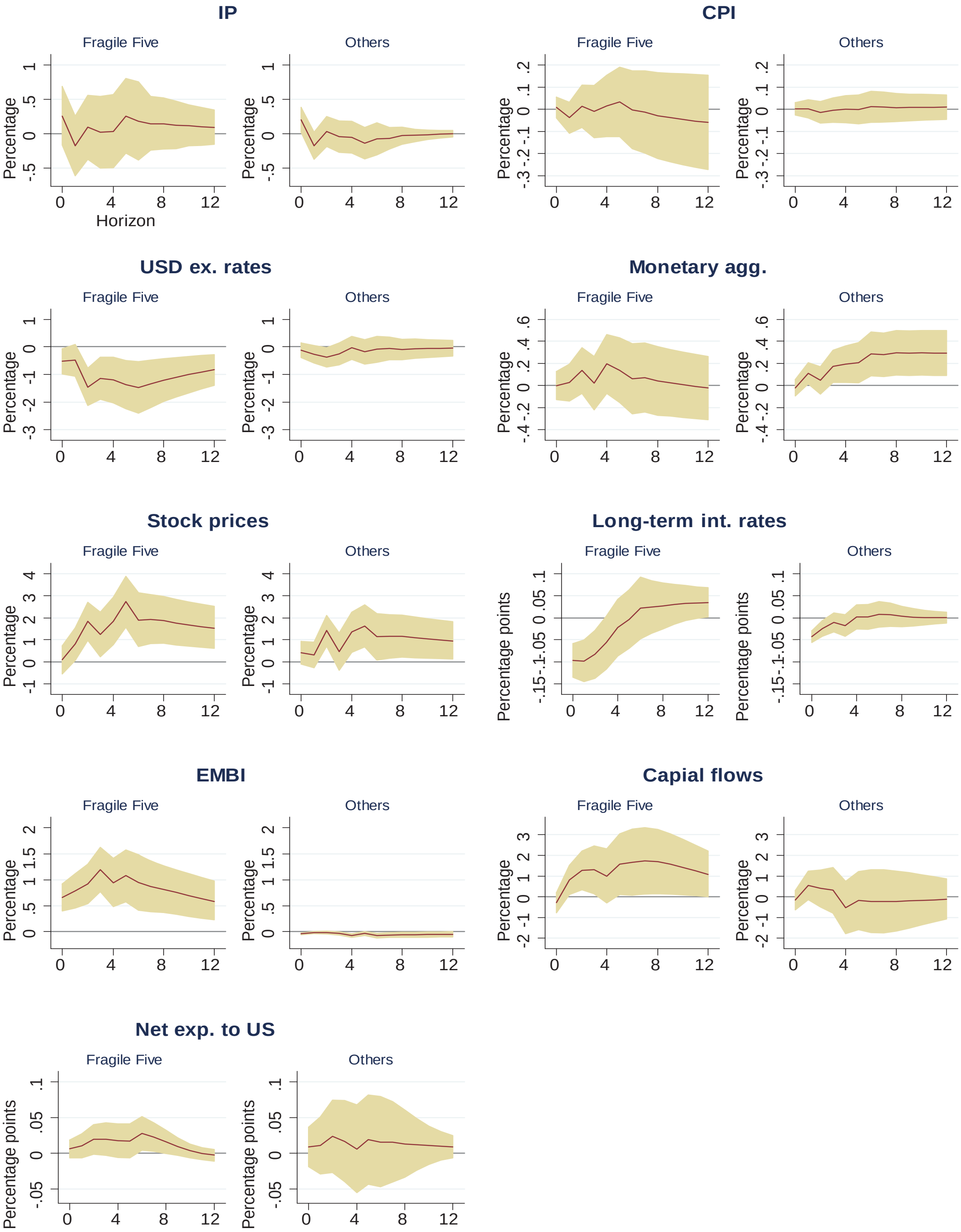


Figure 27: Impulse responses of the panel VAR on Fragile Five and others with announcement date dummies

Notes: Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. See the notes in Figure 7.

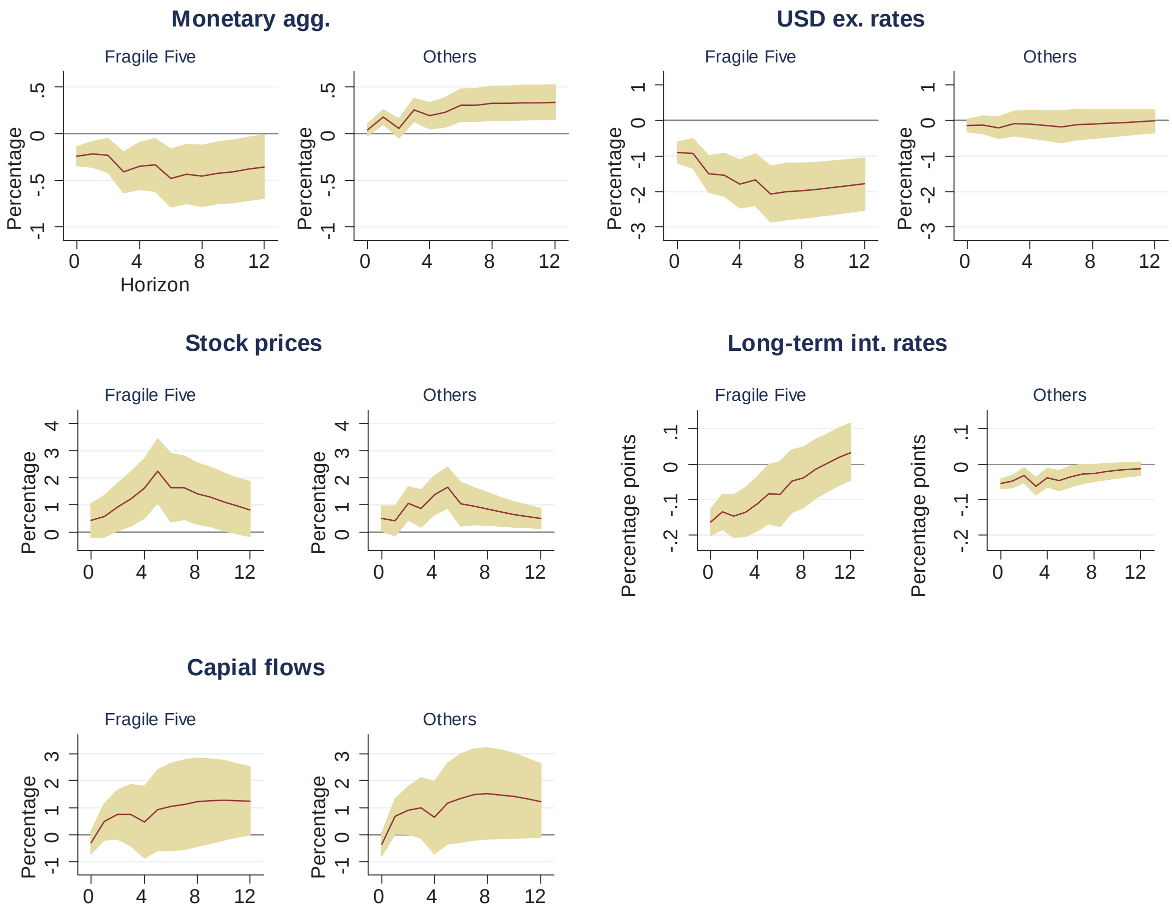


Figure 28: Impulse responses of the panel VAR that includes financial variables only on Fragile Five and others with announcement dates dummies

Notes: Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries including Brazil, India, Indonesia, South Africa and Turkey and the rest of emerging markets. Panel VAR includes financial variables only. See the notes in Figure 7.

C.2.3 Alternate country groups financial VAR

We now present results in Figure 29 from the financial panel VAR specification that includes Mexico with Fragile Five countries as one group and the rest of emerging market economies as another. It is clear that the financial variables respond more strongly for the Fragile Five and Mexico group, with particularly noticeable differences in exchange rates and long-term interest rates. This is similar to the result from the panel VAR that includes macroeconomic variables.

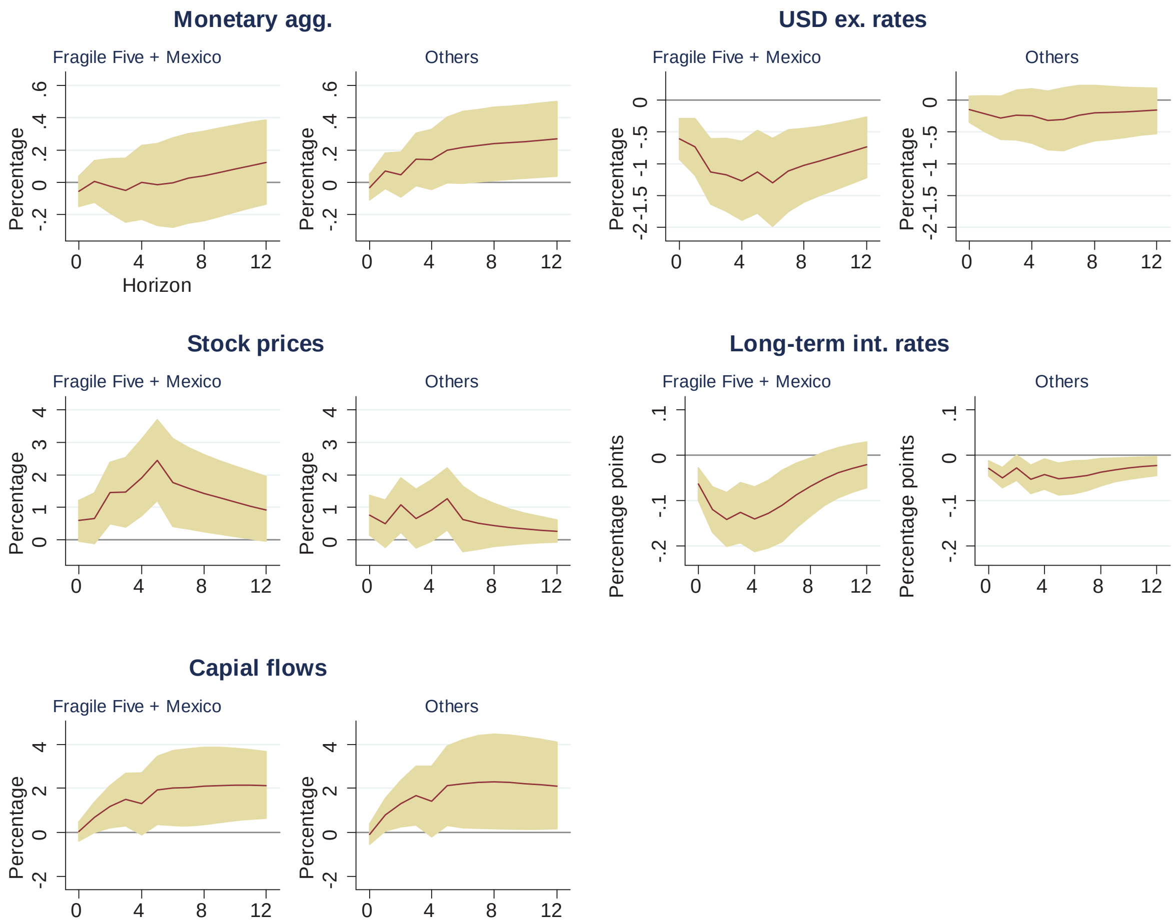


Figure 29: Impulse responses of the panel VAR with Fragile Five plus Mexico and others that includes financial variables only

Notes: Sub-plots are arranged by variables and shown for two groups of countries: the fragile five countries plus Mexico and the rest of emerging markets. Panel VAR includes financial variables only. See the notes in Figure 7.

Online Data Appendix for

Effects of US Quantitative Easing on Emerging Market Economies

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1. US

The data used in the US VAR estimation is described below. The default source of all the US data is FRED, unless otherwise mentioned. All the data below are monthly and the data that are not seasonally adjusted by the data provider are appropriately seasonally adjusted using the X-12 method.

Name	Description	Source	Mnemonic at source
IP	Industrial Production Index, Index 2007=100	FRED	INDPRO
CPI	Consumer Price Index for All Urban Consumers: All Items, Index 1982-84=100	FRED	CPIAUCSL
Securities held outright	Reserve Bank Credit - Securities Held Outright, Billions of Dollars	FRED	WSECOUT
Fed total assets	All Federal Reserve Banks - Total Assets, Eliminations from Consolidation, Millions of Dollars	FRED	WALCL
S&P500	S&P500 index	FRED	SP500
NEER	Narrow Nominal Effective Exchange Rate for United States, 2010=100	FRED	NNUSBIS
10YR Treasury yields	10-Year Treasury Constant Maturity Rate	FRED	GS10
PCE deflator	Personal Consumption Expenditures Deflator: Chain-type Price Index, 2009=100	FRED	PCEPI
Real PCE	Real Personal Consumption Expenditures, Billions of Chained 2009 Dollars	FRED	PCEC96
20YR Treasury yields	20-Year Treasury Constant Maturity Rate	FRED	GS20
7-10YR corporate bond yields	BofA Merrill Lynch US Corporate 7-10 Year Effective Yield	FRED	BAMLC4A0C710YEY
10-15YR corporate bond yields	BofA Merrill Lynch US Corporate 10-15 Year Effective Yield	FRED	BAMLC7A0C1015YEY
30YR mortgage yields	30-Year Fixed Rate Mortgage Average	FRED	MORTGAGE30US
Housing price	National House Price Index	HPI Core Logic	HPI SFC
Real GDP	Interpolated real GDP	Authors'	
Nominal GDP	Interpolated nominal GDP	Authors’	
Vehicle sales	Total Vehicle Sales, Millions of Units	FRED	TOTALSA
Mortgage applications	Total mortgage applications index - refinancing	Datastream	USMAH.A
Mortgage loan size	Mortgage Applications Average Loan size-refinancing	Datastream	USMLH.U
Inflation expectations	5-year Breakeven Inflation Rate	FRED	T5YIEM
Employment	Civilian Employment, Thousands of Person	FRED	CE16OV
PMI	ISM Manufacturing: PMI Composite Index	FRED	NAPM
Coincident Index	Coincident Economic Activity Index for the United States, Index Jul 1992=100	FRED	USPHCI

Nominal and real quarterly GDP are interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production index, civilian employment, personal consumption expenditures, ISM manufacturing: PMI composite index, and the CPI for all urban consumers.

2. World and commodities markets

Name	Description	Source	Mnemonic at source
Commodity price	All Commodity Price Index, 2005 = 100, includes both Fuel and Non-Fuel Price Indices	IMF	PALLFNF
Activities in the commodity market	Kilian real activity index in the commodity markets	Kilian's website	
OECD IP	Total Production of total industry, 2010=100 (all OECD member countries)	OECD	

3. Emerging market countries

The variables used in the panel VAR estimation are described below. The default source of all the emerging market data is Datastream, unless otherwise mentioned. All the data except quarterly GDP are monthly and the data that are not seasonally adjusted by the data provider are appropriately seasonally adjusted using the X-12 method. We use a 3-month moving average of exports and imports to remove noisy fluctuations. Capital flows are the sum of bond market flows and equity market flows.

<Brazil>

Name	Description	Source	Mnemonic at source
IP	Industrial Production Vola	Datastream	BRIPTOT.G
CPI	National CPI Or Inpc Nadj	Datastream	BRCPINATF
MSCI	Msci Brazil - Price Index	Datastream	MSBRAZL
USD Exchange rate	Brazilian Real To Us $ (Br) - Exchange Rate	Datastream	BRUSDSP
Short-term interest rates	Brazilian Real 3m Interest Rate Sw - Middle Rate	Datastream	BRPRE3M
Long-term interest rates	Brazil Government Generic Bond 2 Year	Bloomberg	GEBR02Y Index
Exports to the World	Exports To The World In US Dollars	DOTS/IMF	
Exports to the US	Exports To The US In US Dollars	DOTS/IMF	
Imports from the World	Imports From The World In US Dollars	DOTS/IMF	
Imports from the US	Imports From The US In US Dollars	DOTS/IMF	
Bond market flows	Bond Market Flows In USD Mil	EPFR	
Cumulative bond market flows	Cumulative Bond Market Flows In USD Mil	EPFR	
Equity market flows	Equity Market Flows In USD Mil	EPFR	
Cumulative equity market flows	Cumulative Equity Market Flows In USD Mil	EPFR	
EMBI	JPM EMBI	Datastream	JPMPBRA
Monetary aggregate	Br Monetary Aggregate - M2 (Ep) Curn	Datastream	BRM2....A
Nominal GDP	Interpolated Nominal GDP In Billions of Real	Authors'	

Quarterly GDP	Quarterly Current Price Gross Domestic Product in Billions of Real	FRED	BRAGDPNQDSMEI
Unemployment rates	Unemployment Rate: Aged 15 and Over: All Persons	FRED	LRUNTTTTBRM156N
Retail sales	Total Retail Trade (index, 2010=100)	FRED	BRASARTMISMEI

Nominal quarterly GDP is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, the unemployment rate, and retail sales.

<Chile>

Name	**Description**	**Source**	**Mnemonic at source**
IP	CL INDUSTRIAL PRODUCTION INDEX BY INE - MANUFACTURING TOTAL VOLN	Datastream	CLIPMAN.H
CPI	CL CPI NADJ	Datastream	CLCONPRCF
MSCI	MSCI CHILE - PRICE INDEX	Datastream	MSCHILL
USD Exchange rate	CL EXCHANGE RATE (PESO TO U.S. $)	Datastream	CLXRUSDO
Short-term interest rates	CHILE 3M INTERBANK - MIDDLE RATE	Datastream	CLTAB3M
Long-term interest rates	CL YIELD 10-YEAR GOVERNMENT BONDS NADJ	Datastream	CLMIR080R
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	CL MONEY SUPPLY: M2A (AVERAGE) CURN	Datastream	CLM2....A
Nominal GDP	Interpolated nominal GDP in Billions of Pesos	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in Billions of Pesos	FRED	CHLGDPNQDSMEI
Unemployment rates	Unemployment Rate: Aged 15 and Over: All Persons	FRED	LRUNTTTTCLM156S
Retail sales	CL RETAIL SALES AT SUPERMARKETS (REAL INDEX) VOLN (index, 2009=100)	Datastream	CLRETTOTH
Energy consumption	CL ENERGY CONSUMPTION VOLN (index, 1982=100)	Datastream	CLENERGYH

Nominal quarterly GDP is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, the unemployment rate, retail sales, and energy consumption.

<Colombia>

Name	Description	Source	Mnemonic at source
IP	CB INDUSTRIAL PRODUCTION VOLN	Datastream	CBIPTOT.H
CPI	CB CPI: NATIONAL NADJ	Datastream	CBCONPRCF
MSCI	MSCI COLOMBIA - PRICE INDEX	Datastream	MSCOLML
USD Exchange rate	COLOMBIAN PESO TO US $ - EXCHANGE RATE	Datastream	COLPUSA
Short-term interest rates	CB 3 MONTH RATE, BANK & CORPORATION NADJ	Datastream	CB3MORBC
Long-term interest rates	CB GOVERNMENT BOND YIELD - 10 YEARS (EP)	Datastream	CBGB10..
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	CB MONEY SUPPLY - M2 CURN	Datastream	CBM2....A
Nominal GDP	Interpolated nominal GDP in Billions of Pesos	Authors'	
Quarterly GDP	Quarterly CB GDP (WDA) CURA in in Billions of Pesos	Datastream	CBGDP...B
Capacity utilization	Capacity utilization in percentage	Tradingeconomics	

Nominal quarterly GDP obtained from Datastream is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production and capacity utilization.

<India>

Name	Description	Source	Mnemonic at source
IP	Production of Total Industry in India, seasonally adjusted	FRED	INDPROINDMISMEI
CPI	Consumer Price Index: All Items for India	FRED	INDCPIALLMINMEI
MSCI	MSCI INDIA - PRICE INDEX	Datastream	MSINDIL
USD Exchange rate	US DOLLAR/IND RUPEE FX FIXING - EXCHANGE RATE	Datastream	INUSDRB

Short-term interest rates	INDIA T-BILL 3 MONTH - RED. YIELD	Datastream	INDTB3M
Long-term interest rates	India Govt Bond Generic Bid Yield 10 Year	Bloomberg	GIND10YR Index
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	IN MONEY SUPPLY: M2 (EP) CURN	Datastream	INM2....A
Nominal GDP	Interpolated nominal GDP in Billions of Rupees	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in Billions of Rupees	FRED	INDGDPNQDSMEI
Fuel consumption	IN LIQUID FUELS: CONSUMPTION VOLN in Millions Barrel per day	Datastream	INSLFCONP
Car sales	IN CAR SALES VOLN	Datastream	INCARSALP

Nominal quarterly GDP obtained from FRED is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, fuel consumption and car sales.

<Indonesia>

Name	Description	Source	Mnemonic at source
IP	ID INDUSTRIAL PRODUCTION VOLN	Datastream	IDIPTOT.H
CPI	ID CPI NADJ	Datastream	IDCONPRCF
MSCI	MSCI INDONESIA - PRICE INDEX	Datastream	MSINDFL
USD Exchange rate	National Currency to US Dollar Spot Exchange Rate for Indonesia	FRED	CCUSSP02IDM650N
Short-term interest rates	INDONESIAN INTERBANK 3M - MIDDLE RATE	Datastream	IDIBK3M
Long-term interest rates	ID GOVERNMENT BOND YIELD - 10 YEARS (EP)	Datastream	IDGBOND.
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	

Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	ID MONEY SUPPLY - M2 CURN	Datastream	IDM2....A
Nominal GDP	Interpolated nominal GDP in Trillions of Rupiahs	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in Trillions of Rupiahs	FRED	IDNGDPNQDSMEI
Unemployment rates	ID UNEMPLOYMENT RATE (STANDARDIZED) SADJ	Datastream	IDCUNP..Q
Car sales	ID DOMESTIC VEHICLE SALES - CARS VOLN	Datastream	IDCAR...P

Nominal quarterly GDP obtained from FRED is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, the unemployment rate, and car sales.

<South Korea>

Name	**Description**	**Source**	**Mnemonic at source**
IP	KO INDUSTRIAL PRODUCTION VOLA	Datastream	KOIPTOT.G
CPI	KO CPI NADJ	Datastream	KOCONPRCF
MSCI	MSCI KOREA - PRICE INDEX	Datastream	MSKOREL
USD Exchange rate	SOUTH KOREAN WON TO US $ (KO) - EXCHANGE RATE	Datastream	KOUSDSP
Short-term interest rates	KOREA NCD 91 DAYS - MIDDLE RATE	Datastream	KOCD91D
Long-term interest rates	KO YIELD 10-YEAR GOVERNMENT BONDS NADJ	Datastream	KOOIR080R
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	

Monetary aggregate	KO MONEY SUPPLY - M2 (EP) CURA	Datastream	KOM2....B
Nominal GDP	Interpolated nominal GDP in Trillions of Won	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in Trillions of Korean Won	FRED	KORGDPNQDSMEI
Unemployment rates	Unemployment Rate: Aged 15 and Over: All Persons	FRED	LRUNTTTTKRM156S
Retail sales	Total Retail Trade (index, 2010=100)	FRED	KORSARTMISMEI

Nominal quarterly GDP obtained from FRED is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, the unemployment rate, and retail sales.

<Malaysia>

Name	**Description**	**Source**	**Mnemonic at source**
IP	MY INDUSTRIAL PRODUCTION VOLN	Datastream	MYIPTOT.H
CPI	MY CPI NADJ	Datastream	MYCONPRCF
MSCI	MSCI MALAYSIA - PRICE INDEX	Datastream	MSMALFL
USD Exchange rate	MALAYSIAN RINGGIT TO US $ (BNM) - EXCHANGE RATE	Datastream	MLUSD..
Short-term interest rates	MALAYSIA INTERBANK 3 MONTH - MIDDLE RATE	Datastream	MYIBK3M
Long-term interest rates	MY GOVERNMENT BOND YIELD - 10 YEAR	Datastream	MYGBOND.
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	MY MONEY SUPPLY - M2 (EP) CURN	Datastream	MYM2....A
Nominal GDP	Interpolated nominal GDP in Millions of Riggits	Authors'	
Quarterly GDP growth	real GDP growth rates (quarter-on-quarter)	tradingeconomics	
Electricity consumption	MY ELECTRICITY: LOCAL CONSUMPTION NADJ	Datastream	MYELELCTC

We first construct real GDP by accumulating real GDP growth rates and then disaggregate this real GDP series by the Chow-Lin method into a monthly index, based on the monthly dataset including the industrial production and real electricity consumption. The interpolated monthly index is converted to nominal to match nominal GDP in the fourth quarter of 2014.

<Mexico>

Name	**Description**	**Source**	**Mnemonic at source**
IP	MX INDUSTRIAL PRODUCTION INDEX VOLA	Datastream	MXIPTOT.G
CPI	MX CPI NADJ	Datastream	MXCONPRCF
MSCI	MSCI MEXICO - PRICE INDEX	Datastream	MSMEXFL
USD Exchange rate	MEXICAN PESO TO US $ (MX) - EXCHANGE RATE	Datastream	MXUSDSP
Short-term interest rates	TR MX (MXD) 1M IRS 3M - MIDDLE RATE	Datastream	ICMXN3M
Long-term interest rates	Mexican Federal Treasury Certificate 1YR	Bloomberg	MPTB1 Curncy
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	MX MONEY SUPPLY: M2 (EP) CURN	Datastream	MXM2....A
Nominal GDP	Interpolated nominal GDP in Billions of Pesos	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in Billions of Mexican Pesos	FRED	MEXGDPNQDSMEI
Unemployment rates	Harmonized Unemployment: Total: All Persons for Mexico	FRED	LRHUTTTTMXM156N
Retail sales	Total Retail Trade (index, 2010=100)	FRED	MEXSARTMISMEI

Nominal quarterly GDP obtained from FRED is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, the unemployment rate, and retail sales.

<Peru>

Name	**Description**	**Source**	**Mnemonic at source**
IP	PE INDUSTRIAL PRODUCTION INDEX (STANDARDIZED) VOLA	Datastream	PECIND..G
CPI	PE CPI - LIMA NADJ	Datastream	PECONPRCF

MSCI	MSCI PERU U$ - PRICE INDEX	Datastream	MSPERU$
USD Exchange rate	PERUVIAN SOL TO US $ (EP) - EXCHANGE RATE	Datastream	PEUSDLR
Short-term interest rates	PERU INTERBANK OFFER 3M (ASBANC) - MIDDLE RATE	Datastream	PEBOR3M
Long-term interest rates	PEN deposit rates 1YR	Bloomberg	PSDR1 Curncy
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	PE MONEY SUPPLY - M2 CURN	Datastream	PEM2....A
Nominal GDP	Interpolated nominal GDP in Millions of Nuevo Sol	Authors'	
Quarterly GDP	Quarterly PE GDP CURN in Millions of Nuevo Sol	Datastream	PEGDP…A
Capacity utilization	Capacity utilization in percentage	Tradingeconomics	

Nominal quarterly GDP obtained from Datastream is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production and the capacity.

<South Africa>

Name	**Description**	**Source**	**Mnemonic at source**
IP	SA INDUSTRIAL PRODUCTION (MANUFACTURING SECTOR) VOLA	Datastream	SAIPMAN.G
CPI	Consumer Price Index: All Items for South Africa	FRED	ZAFCPIALLMINMEI
MSCI	MSCI SOUTH AFRICA - PRICE INDEX	Datastream	MSSARFL
USD Exchange rate	SA SOUTH AFRICAN RAND TO US DOLLAR	Datastream	SAXRUSD.
Short-term interest rates	SA TREASURY BILL RATE - 3 MONTH (EP)	Datastream	SAGBILL3
Long-term interest rates	SA GOVERNMENT BOND YIELD - OVER 10 YEARS NADJ	Datastream	SACAP10G
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	

Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	SA MONEY SUPPLY - M2 CURN	Datastream	SAM2....A
Nominal GDP	Interpolated nominal GDP in Billions of Rand	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in South Africa in Billions of South African Rand	FRED	ZAFGDPNQDSMEI
Retail sales	Total Retail Trade (index, 2010=100)	FRED	ZAFSARTMISMEI

Nominal quarterly GDP obtained from FRED is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production and the retail sales.

<Taiwan>

Name	**Description**	**Source**	**Mnemonic at source**
IP	TW INDUSTRIAL PRODUCTION INDEX VOLA	Datastream	TWIPTOT.G
CPI	TW CPI NADJ	Datastream	TWCONPRCF
MSCI	MSCI TAIWAN - PRICE INDEX	Datastream	MSTAIWL
USD Exchange rate	TAIWAN NEW $ TO US $ (WMR) - EXCHANGE RATE	Datastream	TAIWDO$
Short-term interest rates	TAIWAN INTERBANK 3 MONTH - OFFERED RATE	Datastream	TWIBK3M
Long-term interest rates	TW TAIWAN GOVERNMENT BOND YIELD 10 YEAR (EP)	Datastream	TWGBD10Y
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	TW MONEY SUPPLY - M2 (EP) (METHOBRK JAN01) CURN	Datastream	TWM2....A

Nominal GDP	Interpolated nominal GDP in Millions of New Taiwan Dollar	Authors'	
Quarterly GDP	Quarterly TW GDP CURA in Millions New Taiwan Dollar	Datastream	TWGDP…B
Unemployment rates	TW UNEMPLOYMENT RATE SADJ	Datastream	TWUN%TOTQ
Retail sales	TW RETAIL SALES CURN in Millions New Taiwan Dollar	Datastream	TWRETTOTA

Nominal quarterly GDP obtained from Datastream is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, the unemployment rate, and retail sales.

<Thailand>

Name	**Description**	**Source**	**Mnemonic at source**
IP	TH MANUFACTURING PRODUCTION INDEX VOLA	Datastream	THIPMAN.G
CPI	TH CPI NADJ	Datastream	THCONPRCF
MSCI	MSCI THAILAND - PRICE INDEX	Datastream	MSTHAFL
USD Exchange rate	THAI BAHT TO US $ (BOT) - EXCHANGE RATE	Datastream	THUSDSP
Short-term interest rates	BANGKOK INTERBANK 3 MONTH - OFFERED RATE	Datastream	THBIB3M
Long-term interest rates	TH GOVERNMENT BOND YIELD - 10 YEARS	Datastream	THGBOND10
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	TH MONEY SUPPLY: M3 (BROAD MONEY) CURN	Datastream	THM3....A
Nominal GDP	Interpolated nominal GDP in Millions of Baht	Authors'	
Quarterly GDP	Quarterly TH GDP CURA in Millions Thai Baht	Datastream	THGDP…B
Retail sales	TH RETAIL SALES INDEX NADJ	Datastream	THRETTOTF
Electricity cosumption	TH ELECTRICITY CONSUMPTION VOLN in Millions Kilowatt/Hour	Datastream	THELECCNP

Nominal quarterly GDP obtained from Datastream is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production, retail sales, and electricity consumption.

<Turkey>

Name	Description	Source	Mnemonic at source
IP	Production of Total Industry in Turkey	FRED	TURPROINDMISMEI
CPI	Consumer Price Index: All Items for Turkey	FRED	TURCPIALLMINMEI
MSCI	MSCI TURKEY - PRICE INDEX	Datastream	MSTURKL
USD Exchange rate	NEW TURKISH LIRA TO US $ (TK) - EXCHANGE RATE	Datastream	TKUSDSP
Short-term interest rates	TURKISH INTERBANK 3 MONTH - MIDDLE RATE	Datastream	TKIBK3M
Long-term interest rates	USD Turkey Govt Bond Generic Bid Yield 10 Year	Bloomberg	GTRU10YR Index
Exports to the World	Exports to the World in US dollars	DOTS/IMF	
Exports to the US	Exports to the US in US dollars	DOTS/IMF	
Imports from the World	Imports from the World in US dollars	DOTS/IMF	
Imports from the US	Imports from the US in US dollars	DOTS/IMF	
Bond market flows	Bond market flows in USD mil	EPFR	
Cumulative bond market flows	Cumulative bond market flows in USD mil	EPFR	
Equity market flows	Equity market flows in USD mil	EPFR	
Cumulative equity market flows	Cumulative equity market flows in USD mil	EPFR	
EMBI	JPM EMBI	Datastream	
Monetary aggregate	TK MONEY SUPPLY: M2 CURN	Datastream	TKM2....A
Nominal GDP	Interpolated nominal GDP in Billions of Lira	Authors'	
Quarterly GDP	Quarterly Current Price Gross Domestic Product in Turkey in Billions of Turkish Lira	FRED	TURGDPNQDSMEI
Car sales	TK PASSENGER CAR SALES VOLN in Hundreds Actual	Datastream	TKSALCARP

Nominal quarterly GDP obtained from FRED is interpolated by the Chow-Lin method into monthly series, based on the monthly dataset including the industrial production and car sales.