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The shortage of safe assets in the US investment portfolio: Some international evidence[☆]

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Abstract

This paper develops a Bayesian Global VAR (GVAR) model to track the international transmission dynamics of two stylized shocks, namely a supply and demand shock to US-based safe assets. Our main findings can be summarized as follows. First, we find that (positive) supply-sided shocks lead to pronounced increases in economic activity which spills over to foreign countries. The impact of supply-sided shocks can also be seen for other quantities of interest, most notably equity prices and exchange rates in Europe. Second, a demand-sided shock leads to an appreciation of the US dollar and generally lower yields on US securities, forcing investors to shift their portfolios towards foreign fixed income securities. This yields sizable positive effects on US output, equity prices and a general decrease in financial market volatility.

JEL classification: C32, E23, E32

Keywords: Safe Assets, Zero Lower Bound, Treasury Bonds, Shortage, Global VAR.

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1. Introduction

The availability of safe assets during the aftermath of the global financial crisis has gained increasing attention from policy makers, both in advanced and emerging economies.[1] As several assets that belong to the "triple-A" category are not always entirely risk free, financial market participants invest in US treasuries, which are typically considered as risk free. However, during the crisis, the US Fed heavily intervened on the market for long-term US treasury bonds, significantly lowering the availability of safe assets.

The recent shortage of safe assets is not a new phenomenon. Several authors find considerable evidence that the sharp decline in the availability of safe assets translates into increased financial instability and impacts the effectiveness of various economic policy measures. Portes (2011) argues that insufficient supply of safe assets has depressed real interest rates to historical low values, increasing the incentive of investors to search for excessively risky assets with higher returns, such as real estate. Such insufficient supply of safe assets is considered to be a cause of global imbalances and asset bubbles that ultimately culminated in the burst of the US subprime bubble in early 2007. Caballero (2006) states that excess demand of safe assets led to tight spreads, low yields and sharp increases in asset price volatility across advanced economies.[2] DeLong (2012) finds that precautionary motives increased the excess demand for safe assets during the crisis, while supply fell as counterparty risk increased due to information-sensitive debt. Caballero, Farhi, and Gourinchas (2008) show that the inability of emerging markets to supply safe assets led to global imbalances and lowered interest rates across the globe. However, since the global crisis and the recovery thereafter, the gap between the demand and supply of safe assets continues to increase, possibly translating in further financial instability. As a result, insufficient supply or excess demand can determine the shortage of safe assets.

In this paper, we focus attention on US portfolio investment. The US is a special case because prior to the crisis, huge amounts of capital from foreign countries, precisely Asian and oil/commodity producing countries, poured into the US economy through the build-up of dollar denominated reserves.[3] The rest of the world displayed

[1] Safe assets are typically perceived to be a reliable store of value which contains almost no uncertainty about future payments. Moreover, save assets can be used as a collateral and are often utilized as a benchmark to value risky assets.

[2] Caballero (2006) defines this as a bubbly equilibrium.

[3] Ben Bernanke coined this phenomena as the global saving glut hypothesis which led to a long-lasting decrease in real interest rates. The net position in the US has increased enormously, generating a deep current account deficit. However, gross flows are also very important and their increasing trend has gained momentum since the early 2000s. See Johnson (2009); Obstfeld (2012); Shin (2012);

a particular appetite for US Treasury and Agency assets, i.e. safe assets, coupled with the inability of emerging market economies to issue safe assets because of limited institutional capability.[4] Caballero and Farhi (2014) find that such increases in the shortage of safe assets for any given safe interest rate lead to a persistent downward trend in the equilibrium interest rate, which turned the economy in a secular stagnation. During the post-crisis period, the shortage of safe assets has continued as the availability of assets perceived safe was falling due to rating downgrades of sovereigns. Since the financial crisis in 2007, investors faced severe difficulties to find safety and liquidity. Such excess demand results in low yields, tight spreads and higher asset price volatility. As a consequence, advanced economies, in particular the US, have been reallocating assets towards emerging markets. Burger, Sengupta, Warnock, and Warnock (2015) show, for the post-crisis period, that US investors' increasingly raise their exposure with respect to emerging markets, more precisely towards local currency bonds. This finding mainly stems from global "push" factors such as low US long-term interest rates and unconventional monetary policy.

Understanding the consequences of an US based shortage in safe assets is crucial for achieving financial stability. To this aim, we explore the macroeconomic consequences of a supply and demand-sided shortage in US safe assets[5] across the globe. We investigate this shortage by considering a situation where the ZLB is binding or non-binding by performing two counterfactual experiments.[6] In the first experiment we allow short-term interest rates to move freely and in the second experiment we assume that short-term interest rates are effectively constrained by zero.

In order to identify supply and demand-sided shocks for US safe assets, we estimate a global vector autoregressive (GVAR) model over the period ranging from 1994:Q1 to 2014:Q4 for 34 economies. Our modeling approach is based on Feldkircher and Huber (2016) and Crespo Cuaresma, Feldkircher, and Huber (2016), who put forward a Bayesian variant of the GVAR model to alleviate the curse of dimension-

Punzi and Kauko (2015).

[4] See Caballero and Krishnamurthy (2008a) and Caballero and Krishnamurthy (2008b).

[5] In our identification scheme we assume that a positive shock can rise the demand for safe assets because of fear and uncertainty during crisis periods or in times central banks increasingly conduct unconventional monetary policy, while a negative shock can affect the supply of safe assets due to the disappearance of private-label safe assets.

[6] Caballero, Farhi, and Gourinchas (2016) show that, as long as the ZLB is not binding, when shocks hit the economy, the prices of safe assets adjust and interest rates decrease even to negative values to restore equilibrium. At the ZLB, interest rates are not able to dip below zero. This increases the shortage of safe assets in the form of US treasury securities and prevents the price of treasuries to increase in order to satisfy the excess demand. Therefore, investors will not purchase enough treasury securities to sufficiently raise prices (i.e. lower interest rates) and clear the market.

ality. Using a global-local shrinkage prior in the spirit of Griffin and Brown (2005) and applied to the VAR case in Huber and Feldkircher (2016) allows us to shrink the high-dimensional parameter space towards a simpler model specification. To cope with the fact that the volatility of macroeconomic shocks displayed pronounced movements over time, we adopt a stochastic volatility (SV) specification in the spirit of Cogley and Sargent (2005) and utilized in Huber (2016). To identify structural demand and supply shocks we follow Caballero, Farhi, and Gourinchas (2016) and use sign restrictions imposed on the US responses and the average international responses of certain key macroeconomic quantities. On the supply side, as a proxy for the availability of US safe assets, we update data from Gorton, Lewellen, and Metrick (2012) until 2015. Their measure is constructed as the sum of US government debt and the safe component of private financial debt. On the demand side, we use data from Bertaut and Tryon (2007) and Bertaut and Judson (2014) to account for the global demand of US safe assets. Indeed foreigners owned about 71 percent of all US federal government debt in 2015, compared to 20 percent of marketable Treasuries outstanding in 1994.[7]

Our findings indicate that a increase in the supply of US safe assets generates an increase in US real activity. Taking an international stance, this effect spills over to other countries and foreign GDP also increases sharply, as predicted in Caballero, Farhi, and Gourinchas (2015) and Caballero, Farhi, and Gourinchas (2016) (for a negative supply shock). However, this finding arises only for a limited set of countries under consideration, most notably countries that appear to be among the largest (in dollar terms) international investors in the US treasury market. The insufficient supply of US safe assets, coupled with "search for yield" considerations, leads US investor to increase claims versus foreign countries and affect the rest of the world through the portfolio re-balancing channel. Similarly to Bertaut, Tabova, and Wong (2014), we find that since the crisis, foreign countries have expanded their supply of debt securities, meeting the US demand for safe and liquid assets.[8] On the other hand, the global economy tends to be much more reactive with respect to a demand-side shock. US Treasury securities are perceived as a "safe haven" compared with other assets because of low perceived default risk and greater liquidity. As a result, foreign investors

[7]More important aspect is that, among foreign investors, official institutions have taken strong inelastic positions, meaning that the purpose of safe store of value allow them to buy US treasury regardless of prices and interest rates. See Krishnamurthy and Vissing-Jorgensen (2012).

[8]Similarly, Bertaut, Tabova, and Wong (2014) show that post-crisis, US investors have increase their demand for foreign safe assets, with particular interest in Australian and Canadian dollar-denominated debt. Foreign financial sector, contrary to the past, has been active in producing safe assets to meet the increasing US demand.

engaged in a "flight to safety" during pre- and post-crisis periods. We find that higher global demand leads to an increase in US output and to a temporary decrease in the volatility index VIX. Such a surge in capital inflows leads to an appreciation of the US dollar and lower spreads, therefore influencing foreign countries via the liquidity and exchange rate channels. More specifically, foreign output and equity prices increase while interest rates in foreign economies tend to decrease in order to avoid a strong appreciation of the foreign currency.

The rest of the paper is organized as follows: Section 2 provides a comprehensive literature review on the importance of safe assets and international spillover effects. Section 3 discuss the GVAR model adopted in the empirical application. Section 4 describes the data and the identification of demand and supply shocks. Section 5 presents the results. Finally, the last section concludes the paper.

2. Related Literature

This paper relates to different strands of the literature on international finance. First, the paper contributes to the literature on international portfolio allocation and cross-country interdependencies. In a recent contribution, Burger, Sengupta, Warnock, and Warnock (2015) analyze the impact of portfolio re-allocations on US bond portfolios and conclude that global "push" factors, like historically low US long-term interest rates and quantitative easing, have contributed to the increasing demand of US investors for emerging market (EMEs) securities. Burger, Sengupta, Warnock, and Warnock (2015) find that among EMEs, capital flows have been directed to countries with sound macroeconomic fundamentals like low inflation volatility and positive current account balances. Fratzscher (2012) shows that global liquidity and risk largely affect capital flows during periods of crisis and recovery, but the impact is highly heterogeneous, depending on the quality of institutions and the fundamentals of the home country. Mendoza and Terrones (2008), Gourinchas and Obstfeld (2012), Schularick and Taylor (2012) and Forbes and Warnock (2012) show that large debt inflows, in the form of surges and stops, are dangerous because they sharply increase credit and therefore the probability of crises. When capital flows from advanced to emerging economies, real exchange rates tend to appreciate, corporate debt increases and asset prices tick up, leading to adverse effects on financial stability.

Bernanke et al. (2005) and Bernanke et al. (2007) introduced the global savings glut hypothesis, stating that the excess supply of savings relative to investments in surplus countries was channeled into deficit countries, adversely impacting credit conditions. Caballero and Krishnamurthy (2009) explain how foreign demand for safe US dollar-denominated assets leads to a shift towards advanced financial instruments,

stimulating the necessity to create innovative ways of mortgage processing. This led to the creation of low-risk assets that have been strongly demanded by international investors. Thus, such recent developments made it possible to pool loans of low quality and transform them into highly rated securities that have been largely recognized as being safe investments. This in turn had substantial macroeconomic consequences. Capital flows from emerging markets made credit cheap and fueled the boom in asset prices (see, for example, Bertaut, DeMarco, Kamin, and Tryon, 2012).

Another stream of the literature focuses on gross-border banking flows. The findings in Shin (2012) suggest that the loose credit conditions in the US can be attributed to gross cross-border positions rather than net capital flows. Punzi and Kauko (2015) also distinguish between gross and net flows in explaining the US housing and credit boom.

The paper is also closely linked to the literature on the shortage of safe assets and its impact on global interest rates, capital flows and economic crises (Caballero, 2006; Caballero and Krishnamurthy, 2008b; Caballero, Farhi, and Gourinchas, 2008, 2016). This literature explicitly deals with the ZLB. During normal times, countries that are running a current account surplus are tempted to buy foreign safe assets because of insufficient domestic supply. This requires interest rates to decrease in order to restore equilibrium across economies. When the ZLB is binding, interest rates are not able to restore equilibrium, therefore output and exchange rates adjust endogenously, generating a global recession. On the supply side, Krishnamurthy and Vissing-Jorgensen (2012, 2015) show that the decline in the supply of Treasury bonds also exerts downward pressure on yields. The premium associated to those risk-free government securities declines with the total supply of Treasury bonds.[9] If financial sector short-term debt is due to demand for safety/liquidity, then Treasury supply should crowd out financial sector short-term debt via effects on the equilibrium prices of safety and liquidity.

Moreover, the present contribution is also related to the growing literature on trade and financial integration. Dedola and Lombardo (2012) and Perri and Quadrini (2011) show that domestic shocks propagate across countries as asset prices and the cost of credit clear in international markets, while Devereux and Yetman (2010) and Devereux and Sutherland (2011) show how leverage-constrained investors rebalance their diversified international portfolios.

Finally, the paper contributes to the empirical literature on the international transmission of shocks using multi-country VAR models. Canova (2005), using a sign restriction approach to analyze the response of eight Latin American countries to three

[9] Krishnamurthy and Vissing-Jorgensen (2012) label this the "moneyness" premium.

different US shocks, finds that US monetary policy shocks have larger and significant effects on Latin American domestic macroeconomic variables, relative to US aggregate demand and supply shocks. Similarly, Feldkircher and Huber (2016) estimate a GVAR model and find that US based demand, supply and monetary policy shocks generate pronounced international spillovers. Galesi and Sgherri (2009) also utilizes a GVAR model and concludes that in the short run, asset prices are the main channel through which financial shocks are transmitted internationally. Chudik and Fratzscher (2011) employ a GVAR approach to highlight the diversity of the transmission channels. Tightening financial conditions and monetary policy shocks in advanced economies are identified to be important sources of international business cycles and liquidity shocks have been relatively more important for advanced economies than for emerging market economies . By contrast, they find that developing economies were mostly affected by shocks to the risk appetite relative to advanced economies.

3. The econometric framework

This section describes the econometric framework adopted. Section 3.1 briefly discusses the GVAR with stochastic volatility model (GVAR-SV) and describes the features of the model. Section 3.2 provides an overview on the prior setup and the Markov chain Monte Carlo (MCMC) algorithm used.

3.1. A global macroeconomic model

The GVAR model, originally proposed by Pesaran, Schuermann, and Weiner (2004), builds on a set of $N+1$ country-specific VAR models augmented with weakly exogenous regressors that aim to approximate observed or unobserved global factors. These weakly exogenous variables are constructed by taking weighted averages of other countries' endogenous variables.

For a typical country i, we assume that $\boldsymbol{x}_{it}$, a k_i-dimensional vector of endogenous variables, is described by the following VARX*(P,Q) model[10],

$$\boldsymbol{x}_{it} = \boldsymbol{a}_{i0} + \sum_{p=1}^{P} \boldsymbol{\Psi}_{ip}\boldsymbol{x}_{it-p} + \sum_{q=0}^{Q} \boldsymbol{\Lambda}_{iq}\boldsymbol{x}^{*}_{it-q} + \boldsymbol{\varepsilon}_{it}, \tag{3.1}$$

with

- $\boldsymbol{a}_{i0}$ being a k_i-dimensional vector of intercept terms,

[10] In the empirical application we use $P = Q = 2$ lags.

- $\boldsymbol{\Psi}_{ip}$ for $p = 1, \ldots, P$ is a $k_i \times k_i$ matrix of autoregressive coefficients associated with the pth lag of the endogenous variable,

- $\boldsymbol{\Lambda}_{iq}$ for $q = 0, \ldots, Q$ are coefficient matrices associated with the k_i^* *weakly exogenous* variables $\boldsymbol{x}_{it}^*$. The k_i^* weakly exogenous variables in $\boldsymbol{x}_{it}^*$ are constructed by taking weighted averages of other countries' endogenous variables, i.e.

$$\boldsymbol{x}_{it}^* = \sum_{j=0}^{N} w_{ij} \boldsymbol{x}_{jt}. \tag{3.2}$$

  Here we let w_{ij} be a set of bilateral weights between countries i and j that sum to unity.

- Finally, we let ε_{it} be a vector white noise error term with

$$\boldsymbol{\varepsilon}_{it} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_{it}). \tag{3.3}$$

  $\boldsymbol{\Sigma}_{it}$ denotes a time varying variance-covariance matrix of dimension $k_i \times k_i$.

We control for time-variation in the volatility of the structural errors by using a stochastic volatility model. Specifically, we follow Cogley and Sargent (2005) and Huber (2016) and decompose $\boldsymbol{\Sigma}_{it}$ as

$$\boldsymbol{\Sigma}_{it} = \boldsymbol{U}_i \boldsymbol{H}_{it} \boldsymbol{U}_i', \tag{3.4}$$

where $\boldsymbol{U}_i$ is a lower triangular matrix with unit diagonal and typical off-diagonal element $u_{i,jn}$ $j = 2, \ldots, k_i;\ n = 1, \ldots, j-1$. Furthermore we let $\boldsymbol{H}_t$ be a diagonal matrix with typical diagonal element $e^{h_{i,jt}}$ $(j = 1, \ldots, k_i)$. The $h_{i,jt}$'s are log-volatilities that follow an AR(1) process,

$$h_{it} = \mu_i + \rho_i (h_{it-1} - \mu_i) + \nu_{it}. \tag{3.5}$$

In Eq. (3.5), μ_i denotes the mean of the log-volatility, ρ_i the persistence parameter and ν_{it} is a normally distributed zero mean error term with variance ς_i^2. Equation (3.5) assumes that the log-volatility evolves smoothly over time and is stationary. As opposed to the recent macroeconomic literature that typically imposes a random walk state equation this choice rules out explosive behavior of the underlying log-volatility if T becomes large.

Before we derive the global representation of the model a few words on the implications of the model are in order. At the individual country level, the presence of the weakly exogenous variables accounts for the presence of global factors that impacts

all countries simultaneously. The inclusion of these international proxies accounts for cross-country correlation in the errors and allows the country-specific models to be treated as being independent from each other, effectively simplifying the estimation problem at hand considerably. Moreover, our specification of the variance-covariance matrix implies that the volatility of the shocks is smoothly evolving over time. We assume that the autoregressive parameters are constant over time. This assumption is based on the literature on time-varying parameter models that find only limited evidence in favor of structural breaks, especially for US data (for a discussion, see Primiceri, 2005; Koop, Leon-Gonzalez, and Strachan, 2009).[11]

In order to derive the global VAR model it proves to be convenient to set $P = Q = 1$ and work with the VARX*(1,1) model. Rewriting Eq. (3.1) yields

$$\boldsymbol{x}_{it} - \boldsymbol{\Lambda}_{i0} x^*_{it} = \boldsymbol{a}_{i0} + \boldsymbol{\Psi}_{i1} \boldsymbol{x}_{it-1} + \boldsymbol{\Lambda}_{i1} \boldsymbol{x}^*_{it-1} + \boldsymbol{\varepsilon}_{it}, \tag{3.6}$$

which can be further simplified as

$$\boldsymbol{A}_i \boldsymbol{z}_{it} = \boldsymbol{a}_{i0} + \boldsymbol{B}_i \boldsymbol{z}_{it-1} + \boldsymbol{\varepsilon}_{it}. \tag{3.7}$$

Here, we let $\boldsymbol{A}_i = (\boldsymbol{I}_{k_i}, \boldsymbol{\Lambda}_{i0})$, $\boldsymbol{B}_i = (\boldsymbol{\Psi}_{i1}, \boldsymbol{\Lambda}_{i1})$ and $\boldsymbol{z}_{it} = (\boldsymbol{x}'_{it}, \boldsymbol{x}^{*'}_{it})'$. Introducing a so-called global vector $\boldsymbol{x}_t = (\boldsymbol{x}'_{0t}, \ldots, \boldsymbol{x}'_{Nt})'$ of dimension $k = \sum_{j=0}^{N} k_j$ and a suitable $(k_i + k_i^+) \times k$ linking matrix $\boldsymbol{W}_i$ allows us to state $\boldsymbol{z}_{it}$ in terms of the global vector,

$$\boldsymbol{z}_{it} = \boldsymbol{W}_i \boldsymbol{x}_t. \tag{3.8}$$

Stacking the equations for each country finally yields

$$\boldsymbol{G} \boldsymbol{x}_t = \boldsymbol{b}_0 + \boldsymbol{F} x_{t-1} + \boldsymbol{\varepsilon}_t \tag{3.9}$$

where

$$\begin{aligned}
\boldsymbol{b}_0 &= (\boldsymbol{a}'_{00}, \ldots, \boldsymbol{a}'_{N0})', \\
\boldsymbol{G} &= ((\boldsymbol{A}_0 \boldsymbol{W}_0)', \ldots, (\boldsymbol{A}_N \boldsymbol{W}_N)')', \\
\boldsymbol{F} &= ((\boldsymbol{B}_0 \boldsymbol{W}_0)', \ldots, (\boldsymbol{B}_N \boldsymbol{W}_N)')', \\
\boldsymbol{\varepsilon}_t &= (\boldsymbol{\varepsilon}'_{0t}, \ldots, \boldsymbol{\varepsilon}'_{Nt})'.
\end{aligned}$$

[11] Allowing for time-variation in the parameters in a GVAR framework has been introduced by Crespo Cuaresma, Doppelhofer, Feldkircher, and Huber (2016). However, in that contribution the number of endogenous variables at the individual country level appears to be much smaller as compared to the present application.

The errors in ε_t feature a variance-covariance matrix that is block-diagonal with $\boldsymbol{\Sigma}_{it}$ being in the ith diagonal block of this matrix.

After multiplying with $\boldsymbol{G}^{-1}$ from the left the model can be used to perform structural analysis or forecasting. In addition, the matrix $\boldsymbol{G}$ serves to establish contemporaneous relationships between countries in our system of equations.

3.2. Bayesian inference

Because the model outlined in the previous subsection is heavily parameterized and the time span we cover rather limited, we adopt a Bayesian approach to estimation and inference. This implies that we have to specify a suitable set of prior distributions on the parameters in Eq. (3.1) and Eq. (3.5). Our prior setup is a variant of the Normal-Gamma (NG) prior stipulated in Griffin and Brown (2005) and applied to the VAR case in Huber and Feldkircher (2016).

It proves to be convenient to collect all slope coefficients and the intercept in a generic matrix $\boldsymbol{\Xi}_i$ with typical element ξ_{ij} $(j = 1, \ldots, K_i)$ where $K_i = k_i(1 + k_i \times P + k_i^* \times (Q + 1))$ denotes the number of autoregressive coefficients in country i's model.

We impose a normally distributed prior on the elements of $\boldsymbol{\Xi}_i$,

$$\xi_{ij}|\tau_{ij}^2, \lambda_i^2 \sim \mathcal{N}(0, 2/\lambda_{\xi i}^2 \tau_{ij}^2), \tag{3.10}$$

$$\tau_{ij}^2 \sim \mathcal{G}(\vartheta_{\tau i}, \vartheta_{\tau i}), \tag{3.11}$$

$$\lambda_{\xi i}^2 \sim \mathcal{G}(\kappa_{\xi 0}, \kappa_{\xi 1}), \tag{3.12}$$

where τ_{ij}^2 are local shrinkage parameters that apply an individual degree of shrinkage to each coefficient in the model, $\lambda_{\xi i}^2$ is a country-specific shrinkage parameter that exerts shrinkage on the full matrix $\boldsymbol{\Xi}_i$. On both, the local and the country-specific shrinkage parameters, we impose a set of Gamma priors with hyperparameters $\vartheta_{\tau i}$, $\kappa_{\xi 0}$ and $\kappa_{\xi 1}$. This prior setup provides significant flexibility by inducing a heavy tailed marginal prior on ξ_{ij} implying that this prior setup allows for non-zero coefficients even in the presence of heavy country-specific (overall) shrinkage stemming from $\lambda_{\xi i}^2$. In the empirical application we set $\kappa_{\xi 0} = \kappa_{\xi 1} = 0.01$ to induce large amounts of shrinkage on all coefficients of a given country and set $\vartheta_{\tau i} = 0.6$ for all countries. Note that $\vartheta_{\tau i} = 1$ would lead to the Bayesian LASSO (see, for example, Kozumi and Kobayashi, 2011; Gefang, 2014).

For the variance-covariance matrix we impose the same set of normally distributed

priors on the the free elements of $\boldsymbol{U}_i$,

$$u_{i,jn} \sim \mathcal{N}(0, 2/\lambda_{ui}^2 \phi_{i,jn}^2), \tag{3.13}$$
$$\phi_{i,jn}^2 \sim \mathcal{G}(\vartheta_{\phi i}, \vartheta_{\phi i}), \tag{3.14}$$
$$\lambda_{ui}^2 \sim \mathcal{G}(\kappa_{u0}, \kappa_{u1}). \tag{3.15}$$

The hyperparameters are defined analogously to the case of the prior on $\boldsymbol{\Xi}_i$. This prior specification allows for shrinkage on the covariance parameters of the variance-covariance matrix, where the country-specific shrinkage parameter λ_{ui}^2 pulls all covariance parameters towards zero and the individual shrinkage parameters $\phi_{i,jn}^2$ provide the possibility to allow for non-zero covariance parameters even if λ_{ui}^2 is large.

Finally, we follow Kastner and Frühwirth-Schnatter (2013) and use a normally distributed prior on μ_i, i.e. $\mu_i \sim \mathcal{N}(0, 10^2)$, a Beta distributed prior on ρ, $\frac{\rho+1}{2} \sim \mathcal{B}(25, 5)$ and a Gamma prior on $\varsigma_i^2 \sim \mathcal{G}(1/2, 1/2)$. The prior on μ_i is specified to be rather uninformative while the prior on ρ_i places sufficient mass on high persistence regions of the parameter space. The Gamma prior on ς_i^2 translates into a normally distributed prior on $\pm\varsigma_i$ with mean zero and variance unity.

Estimation is carried out on a country-by-country basis as described in Crespo Cuaresma, Feldkircher, and Huber (2016). Fortunately, most conditional posterior distributions take convenient forms, rendering simple Gibbs steps feasible. For some parameters, however, we use a low-dimensional random walk Metropolis Hastings update. More details of the corresponding MCMC algorithm are available in Huber and Feldkircher (2016). For all results presented below we simulate a Markov chain with 30,000 iterations where we discard the first 15,000 as burn-in.

4. Data overview and model specification

Our dataset comprises a broad set of 34 developed and developing countries[12] that cover over 90% of global output measured over the time period ranging from 1994:Q1 to 2014:Q4.

For a typical country i, we include a broad battery of macroeconomic and financial variables to approximate demand and supply-sided movements as well as financial

[12] More specifically, the countries included are Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Greece (GR), Italy (IT), Netherlands (NL), Portugal (PT), Australia (AU), Canada (CA), Switzerland (CH), Japan (JP), Norway (NO), Sweden (SE), United Kingdom (UK), United States (US), Argentina (AR), Brazil (BR), Chile (CL), China (CN), Indonesia (ID), India (IN), South Korea (KR), Mexico (MX), Malaysia (MY), Peru (PE), Philippines (PH), Singapore (SG), Thailand (TH), South Africa (ZA), Turkey (TR), Denmark (DK).

market behavior. More precisely, we consider the following variables in our GVAR estimation,

$$\boldsymbol{x}_{it} = (y_{it}, Dp_{it}, rer_{it}, stir_{it}, rp_{it}, eq_{it}, Liab_{it}, Claims_{it}, swaps_{it})'.$$

Here, we let y_{it} denote real GDP, Dp_{it} denotes CPI inflation, rer_{it} is the real exchange rate measured against the US dollar so that $\Delta rer_{it} > 0$ implies an appreciation of the US dollar, $stir_{it}$ are short-term interest rates (three-month money market rates) and rp_{it} denotes the risk premium, measured by taking the difference between ten-year government bond yields in country i and the corresponding ten-year yield on US treasuries. Moreover, we let eq_{it} be the log of the largest equity price index in each country to approximate movements in asset prices. $Liab_{it}$ measures the foreign holdings of US long-term securities, $Claims_{it}$ represents the US holdings of foreign long-term debt securities and $swaps_{it}$ are the US Fed swap lines.[13] The US country model differs slightly because we also include data on the volatility index (labeled $VIX_{US,t}$ and the ratio of US safe assets to GDP ($\frac{SA_{US,t}}{y_{US,t}}$, labeled $safe_{US,t}$).

The weakly exogenous variables included are symmetric except for the real exchange rate, which are only included as a weakly exogenous variable in the US country model. This implies that $\boldsymbol{x}_{it}^*$ features the same set of variables as $\boldsymbol{x}_{it}$, excluding the real exchange rate, for all countries except the US.

$safe_{US,t}$ is used to represent the supply of US safe assets. We rely on Gorton, Lewellen, and Metrick (2012)'s list of safe assets in constructing this series with the corresponding data stemming from the US Flow of Funds.[14] This measure pools data on the liabilities of financial intermediaries and the government that are information-insensitive, i.e. securities whose value is immune to adverse selection in exchange, and thus reduces the incentive of traders to verify the assets' creditworthiness. The safe asset measure is constructed as the sum of US government debt and the safe component of private financial debt.[15] According to Gorton, Lewellen, and Metrick (2012), deposits are the most obvious example of safe assets, despite the fact that Treasury and Agency assets are also information-insensitive and share other typical

[13] Data include all operations conducted between the Federal Reserve and the Bank of Canada, the Bank of England, the Bank of Japan, the European Central Bank, the Swiss National Bank, the Reserve Bank of Australia, the Bank of Korea and the Bank of Mexico between the forth quarter of 2007 and the third quarter of 2010.

[14] See the Data Appendix in Gorton, Lewellen, and Metrick (2012) for details of the corresponding composition of this measure.

[15] Alternative measures of the availability of US safe assets can be found in Bertaut, Tabova, and Wong (2014). They consider only the availability of safe assets to private investors, therefore they exclude from Gorton, Lewellen, and Metrick (2012)'s share the holdings of safe assets by the Federal Reserve and by foreign official investors.

characteristics of safe assets.[16] Gorton, Lewellen, and Metrick (2012) also compute an "high" and "low" estimate of the amount of safe debt in the US. The *high* category includes all government and financial-sector liabilities, which largely comprise Treasuries, municipal bonds, short-term and long-term corporate debt, securitized debt, and other miscellaneous liabilities, while the *low* category excludes miscellaneous financial liabilities, loans, a number of accounts involving payables, and other liabilities that are not routinely traded. In our estimation, we consider only the *high*-type of safe assets because we assume that the insufficient availability of safe assets is mainly due to the decreasing amount of treasuries and securitized debt.

On the demand side, we use data from Bertaut and Tryon (2007) and Bertaut and Judson (2014) to construct a measure for the demand of US safe assets from abroad.[17] In particular, we combine the demand for US treasury and agency bonds from foreign investors (see Table 1, Panel "liabilities").

In order to evaluate the international impact of increasing demand or decreasing supply of US safe assets, we measure the implications on capital outflows from the US to the rest of the world with the aim to highlight the increasing appetite of US investors for foreign safe assets in their search for yield (see Table 1, Panel "assets"). During the post-crisis period, the Federal Reserve has absorbed more than half of the increase in outstanding safe government debt through different large scale asset purchasing programs, implying that less safe assets have been available to private investors. As a result, US investors displayed increasing demand for foreign safe assets, which is in contrast to their past behavior.[18] Table 1 shows that the foreign holdings of US long-term securities have been considerably larger than the foreign securities held by US residents, and the net US position in long-term securities continued to decline over time. However, since the implementation of quantitative easing measures and the hit of the ZLB, the ratio of US to foreign holdings approached 60 percent in 2015 from an initial 54 percent in 2009, meaning that US residents increasingly shifted investment opportunities towards advanced and emerging economies.[19]

Before proceeding to the next subsection a brief word on the specification of the

[16] Another important role of safe assets and highly-rated government is that they can act as collateral in financial transactions, mimicking the role of money.

[17] Bertaut and Judson (2014) estimate the demand for monthly US cross-border securities, combining information from detailed annual Treasury International Capital (TIC) surveys with new information from the TIC form SLT, "Aggregate Holdings of Long-Term Securities by US and Foreign Residents." Bertaut and Judson (2014) decompose monthly data into flows, estimated valuation changes, and a residual gap in order to incorporate additional adjustments to the transactions data and survey data.

[18] See Bertaut, Tabova, and Wong (2014).

[19] In particular, Bertaut, Tabova, and Wong (2014) report that US investors have increase their demand for Australian and Canadian dollar-denominated debt.

Table 1: Market value of U.S. holdings of foreign long-term securities and foreign holdings of U.S. long-term securities, as of selected survey dates. (Billions of dollars)

	U.S. holdings of foreign long-term securities (assets)	Foreign holdings of U.S. long-term securities (liabilities)	U.S. holdings as a share of foreign holdings (assets/liabilities)	Net asset positions in long-term securities of U.S. residents
Dec. 1994	870	1,244	0.7	-374
Mar. 2000	2,678	3,558	0.75	-880
Jun. 2002	2,129	3,926	0.54	-1,797
Jun. 2003	2,367	4,503	0.53	-2,136
Jun. 2004	3,027	5,431	0.56	-2,404
Jun. 2005	3,728	6,262	0.6	-2,534
Jun. 2006	4,799	7,162	0.67	-2,363
Jun. 2007	6,429	9,136	0.7	-2,707
Jun. 2008	6,324	9,463	0.67	-3,139
Jun. 2009	4,615	8,492	0.54	-3,877
Jun. 2010	5,282	9,736	0.54	-4,454
Jun. 2011	6,830	11,561	0.59	-4,731
Jun. 2012	6,834	12,451	0.55	-5,616
Jun. 2013	7,842	13,532	0.58	-5,691
Jun. 2014	9,603	15,539	0.62	-5,936
Jun. 2015	9,737	16,202	0.6	-6,465

Source: Foreign Portfolio Holdings of U.S. Securities as of 6/30/2015 from the T.I.C System. Net foreign holdings are defined as U.S. holdings of foreign securities minus foreign holdings of U.S. securities.

weighting matrices is in order. In the following application we have decided to rely on average trade weights over the estimation sample to connect the country-specific VAR models. This choice is based on comparing a set of different weighting schemes. Specifically, we use trade weights at the start of the sample, weights based on simple geographical distances, weights based on bilateral FDI flows and a mixture of trade weights to connect real variables and weights based on bilateral banking exposure to link financial variables together. For each of these different weighting schemes we compute the deviance information criterion (DIC, see Spiegelhalter, Best, Carlin, and Van Der Linde, 2002) and pick the model that yields the lowest DIC. In our case, average trade weights outperform all competing weights, with performance gains vis-a-vis all schemes except the mixed scheme being particularly pronounced. In the mixed case, however, the differences are rather small, corroborating the findings in Feldkircher and Huber (2016). However, after estimating the model and the corresponding impulse responses with the mixed scheme we find no discernible differences between our findings and thus opt for the simpler specification.

4.1. Identification

We carefully follow the IS-LM/Mundell-Fleming framework adopted by Caballero, Farhi, and Gourinchas (2016) to identify supply and demand shocks in the US safe asset market. In contrast to Caballero, Farhi, and Gourinchas (2016) we perform two counterfactual exercises. In the first one (our baseline) we assume that the ZLB binds only on impact, implying that the central bank reacts sluggishly with respect to supply and demand shocks. The second scenario assumes that the policy rate is deemed to remain at zero over the impulse response horizon.[20]

Our approach to identification is based on sign restrictions as proposed by Uhlig (2005), where we apply the algorithm of Rubio-Ramírez, Waggoner, and Zha (2010). More specifically, we identify supply and demand shocks by using the set of restrictions shown in Table 2. The restrictions we impose are as follows. A shrinking supply of safe assets in the US, i.e. a decrease in $safe_{US,t}$, leads to a *persistent* reduction[21] in output (under the assumption that US output decreases over the first ten quarters) and an increase in the risk premium. Caballero, Farhi, and Gourinchas (2016) show that a central bank could avoid the output reduction by lowering the interest rate. However, during periods of the ZLB, this is not feasible and the country enters a liquidity trap. As countries are strongly interconnected, and still considering the inability to use the interest rate to re-balance the shortage, the exchange rate plays a crucial role in the adjustment process. As a result, the US dollar depreciates and the valuation effect reduces the scarcity of safe assets (in dollar terms). However, even if the exchange rate works in order to restore equilibrium, the US still suffers a rather pronounced drop in real activity. For the remaining variables, we impose no further restrictions (see Table 2, column 1).

In identifying demand shocks, we assume that a positive shock to the liabilities on foreign countries, , i.e. an increase in $Liab$, generates an increase in output and the return on safe assets, that means income is allocated and reinvested into safe assets, leading to a decrease in the risk premium (see Table 2, second column). Technically, this is implemented by simultaneously shocking the bond time series for the six countries that display the highest share of liabilities, i.e. foreign demand of US safe assets (treasury and agency bonds).[22] US interest rate responses equal zero because nominal short-term interest rates are bound by the ZLB initially. Increasing capital inflows in the US lead to a drop in the long-term interest rate, which translates into

[20] Within the GVAR framework this implies that we zero-out the structural coefficients of the monetary policy rule for the US country model over the impulse response horizon.

[21] Here we define the sign restrictions in terms of a negative supply shock. In the following application we consider a positive supply shock for exposition purposes.

[22] In our case, the countries are Germany, Switzerland, China, Korea, Japan and the United Kingdom.

a drop in the risk premium. This means that investors are searching for yield given the ultra-low level of US interest rates. As shown in Mendicino and Punzi (2014), Punzi and Kauko (2015) and Sá and Wieladek (2015), the increase in the perceived safety of US bonds encourages foreign investors to reallocate parts of their savings to domestic assets. However, the ZLB and the quantitative easing policy, which tend to limit investment opportunities for US residents, lead a redistribution of resources away from the US towards foreign economies, leading to a future reduction in the US output and an increase in foreign output. Foreign interest rates decrease, reflecting the increase in demand for foreign bonds and the reduction in demand for US safe assets. Currencies appreciate and risk premia decrease, making it easier for US residents to invest abroad. The greater availability of US funds in foreign economies generates a greater availability of credit, leading to credit and asset price booms.

Table 2: Sign Restrictions

Variables	Supply Shock (1)	Demand Shock (2)
$safe_{US,t}$	+	?
$Liab_{it}$	?	+
$Claims_{it}$	?	?
$stir_{US,t}$	0	0
$stir_{it}$	?	?
$y_{US,t}$	-	+
y_{it}	?	?
$Dp_{US,t}$	?	?
Dp_{it}	?	?
rp_{it}	+	-
$eq_{US,t}$	?	?
$VIX_{US,t}$	?	?
rer_{it}	-	-

Notes: Responses marked with ? are left unrestricted. Restrictions on countries other than the US are imposed on average and all restrictions are imposed on impact except for US GDP responses to an supply shock. There we impose the restriction that responses have to be above zero for the first ten quarters.

5. Dynamic responses to supply and demand sided safe asset shocks

In this section we examine the impact of demand and supply shocks to safe assets on the US economy. Additionally, we also assess the effect on the global economy by analyzing the macroeconomic responses of each country in our dataset which covers a broad range of emerging (EE) and advanced economies (AE). However, due to space restrictions, we report impulse responses only for the US and for the remaining countries we rely on four simple regional averages (Western Europe, Asia, Latin America and Other developed economies).[23] These plots aim to provide an overview on the dynamic responses of our endogenous variables. It is noteworthy that the corresponding credible sets do not only include estimation and identification uncertainty[24] (as in the case of country-specific impulse responses) but also capture uncertainty related to within-group heterogeneity. Thus, to provide another gauge on the statistical significance of our findings we also report boxplots along with 25th and 75th credible sets that depict the maximum response of a given variable for selected countries.[25] Furthermore, while we are interested in a negative supply shock to US safe assets we multiply the corresponding IRFs by -1 to obtain positive supply shocks to ease comparison between both shocks in the following application.

To evaluate the impact of the ZLB on our findings we moreover report the posterior median estimate of both shocks when we impose the ZLB constraint. Since the ZLB has been binding only in recent years for most countries we view the responses with interest rates unrestricted as our baseline scenario while the restrictions imposed on short-term interest rate reactions may be viewed as a hypothetical scenario if the ZLB would have been binding in the past.

5.1. Dynamic responses of the United States to supply and demand side safe asset shocks

Figure 1 displays responses to a one standard deviation[26] positive demand shock (first two columns on the left side) and one standard deviation positive supply shock (last two columns on the right). The blue shaded areas represent 25th and 75th credible sets with the posterior median in dark blue and the median of the responses under the ZLB constraint in orange.

[23] We opt for simple averages to avoid our results being driven by a few large countries.

[24] Since we rely on sign restrictions we do not obtain exact identification but rather set identification, implying that the posterior uncertainty associated with the impulse response functions is further inflated.

[25] The countries included are the DE, BE,FR,IT , France and the UK (Western Europe group), CN, IN, MY and PH (Asia group), BR, CL, MX and PE (Latin America group) and US, CA, JP, NZ and ZA (Other developed economies group).

[26] Due to the SV specification we pick the last time point in our estimation sample.

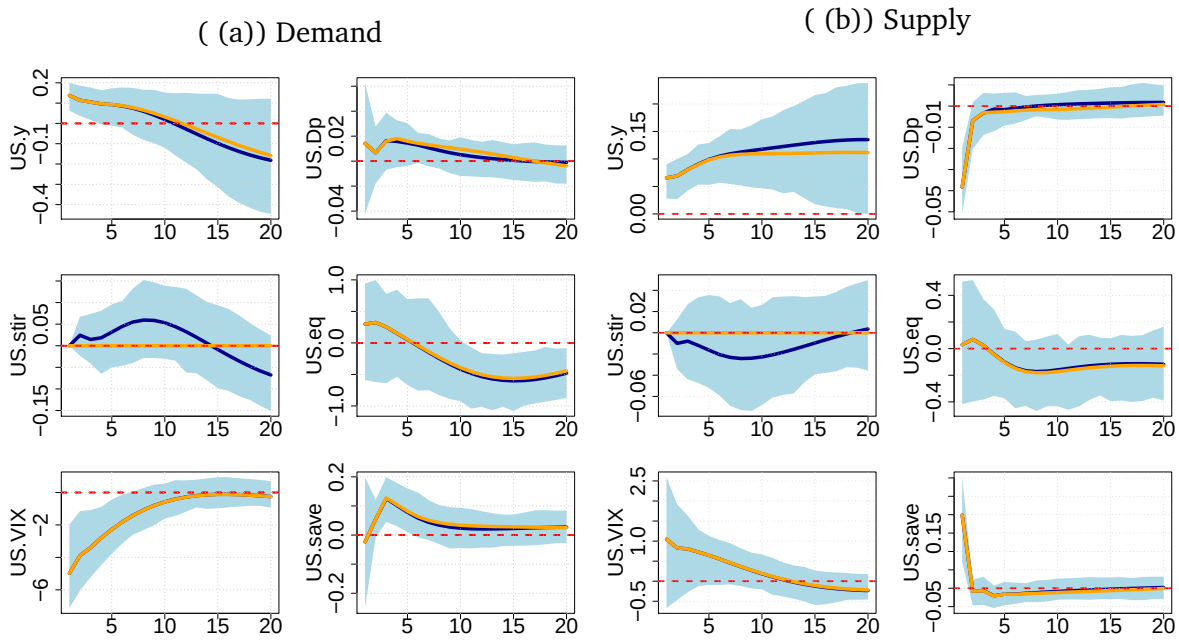
A safe asset demand shock leads to a positive reaction of US GDP, which increases by around 0.15 percent. The response is positive during the first five quarters, and turns insignificant afterwards. Inflation responses are rather muted, being insignificant over the impulse response horizon. By construction, the response of the policy rate is zero initially, but allowed to move freely under the baseline scenario. Interestingly, policy responses appear to be insignificant afterwards. By contrast, the orange line remains stuck at zero, capturing the notion that the central bank is not capable of moving interest rates when the ZLB is hit.

Turning to the reaction of the stock market, we see that initially, markets tend to react in an insignificant fashion but display a pronounced decline after around five quarters. We conjecture that the mixed effect at the short-end of the impulse response horizon is due to two opposing sources. Equity prices might profit from more favorable economic conditions in the US. However, given that the risk appetite of US investors translates into increased demand for foreign bonds, financial market participants sell US stocks, leading to declines in equity prices. Both effects might offset each other initially, but the latter mechanism seems to be dominating at longer impulse response horizons.

Volatility in financial markets, as measured by the VIX, decreases on impact by five percent according to the posterior median. The decrease in the VIX reflects an improvement in market confidence and a flattening of the yield curve, as investors re-balance their portfolios. Such lower perceived risk and uncertainty boosts capital inflows and compresses risk premia. Similar results are found in Bruno and Shin (2015).

The supply shock leads to a rather long-lived reaction of US GDP and a short-lived negative reaction of inflation. The decline in US output is in line with Caballero, Farhi, and Gourinchas (2016), who show that when the scarcity of assets increases, equilibrium in the market of safe assets is achieved by a reduction of output if the interest rate hits the ZLB. The VIX tends to increase during the first ten quarters and slightly decreases afterwards. Movements in equity prices appear to be insignificant, suggesting that improved economic conditions and the increase in economic uncertainty yield mixed evidence in terms of equity market dynamics.

The impact on the interest rate is zero on impact. However, similarly to the case of a demand-based shock we find no statistically robust reaction of the central bank. Interestingly, comparing the posterior median responses of all quantities under the ZLB condition (i.e. with the structural coefficients of the monetary policy rule in the US model zeroed out) we find only slight differences relative to the baseline scenario, with all responses being within the credible set of the baseline scenario.



Notes: Posterior distribution of impulse responses in percentage points. Median in black. Dotted blue lines correspond to the 16th and 84th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line.

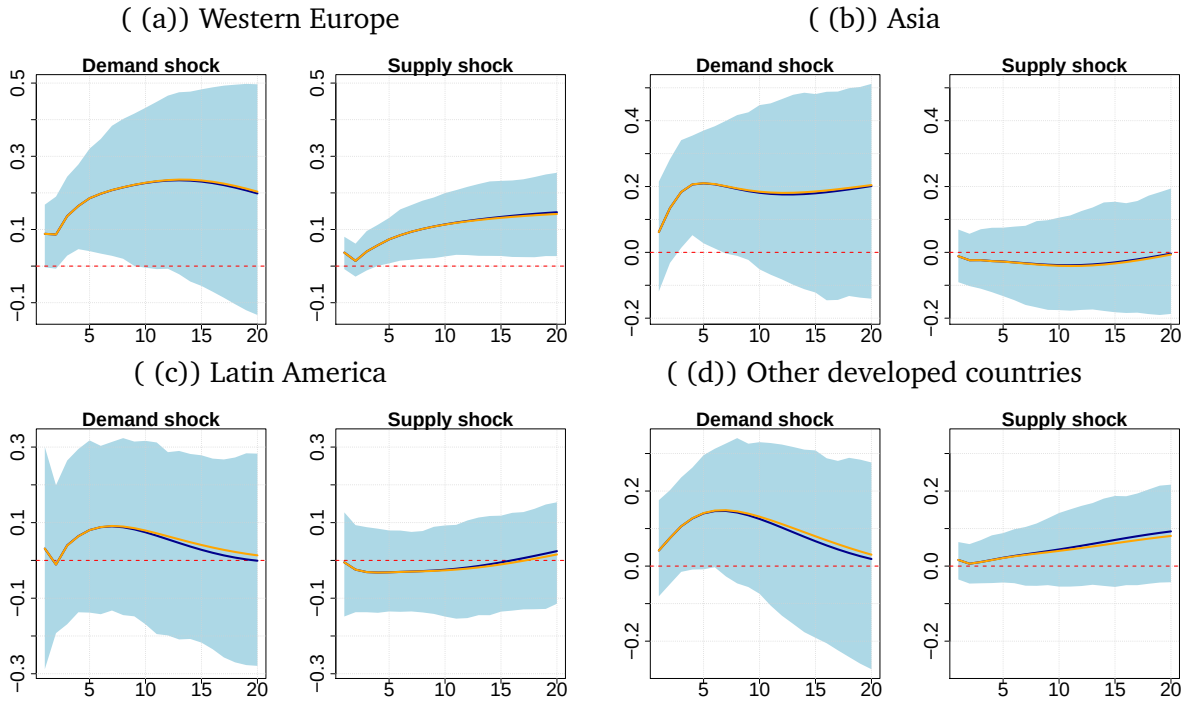
Figure 1: US domestic reactions

5.2. International responses

Figure 2 shows the output reaction to demand and supply shocks for the four regional aggregates. Similarly to the US case, a shock to the supply of US safe assets yields rather mixed output reactions across the globe. Only economies located in western Europe and other developed countries display a positive reaction in terms of real GDP, while countries located in Asia and Latin America do not display such a pronounced increase. As noted in the introduction to this section, this finding can be traced back to at least two sources, namely parameter uncertainty and intra-group heterogeneity. The latter issue will be investigated in more detail below. It is noteworthy that especially countries in Western Europe mirror the persistent increase in US output sharply.

By contrast, demand shocks generate a positive reaction of output for most countries under scrutiny, with the exception of Latin America. Output reactions appear to be rather long lasting for the majority of countries. This result corroborates theoretical findings that establish a positive relationship between capital inflows and economic growth, i.e. foreign funding exerts downward pressure on interest rates

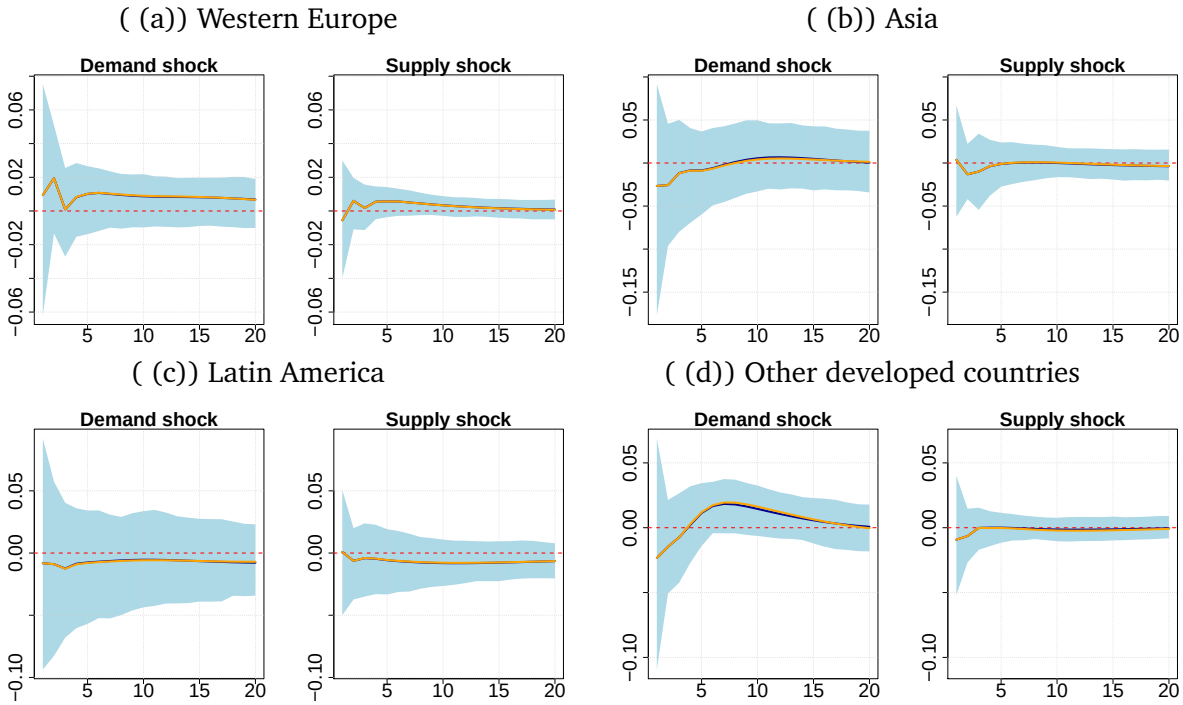
and thus stimulates the economy (see Figure 2). Across regions, output responses with respect to demand-sided shocks appear to be rather homogeneous, while the responses to supply shocks are more heterogenous. This suggests that excess demand of US safe assets stimulates foreign output through the portfolio rebalancing channel. As shown in Caballero, Farhi, and Gourinchas (2015, 2016), the reaction of output depends on the degree of financial integration across economies and whether the ZLB is reached. The question whether the ZLB is reached is important because the inability of short-term interest rates to reach an equilibrium implies that GDP reactions tend to endogenously react to account for this fact. To assess whether this theoretical finding holds within our empirical framework, we compare the responses obtained under our baseline identification with the ones obtained by imposing the ZLB constraint in the US. These findings indicate that output responses only differ marginally, suggesting that when it comes to the international transmission of the shocks, the question whether interest rates are constrained by zero only plays a rather limited role.



Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 2: Output reactions

The impact of supply and demand shocks on international inflation appears to be rather weak (see Figure 3). While the posterior median of each group-specific response is above zero, we again see that the credible sets contain zero in all cases and under both shocks considered. In fact, zooming in the different regions reveals that the only countries that react in a significant fashion to a supply shock are France and Italy (see the discussion below and Figure 10). However, in the case of a demand-sided shock, the country-specific results reveal that inflation in Germany, Belgium and New Zealand increases while Chinese CPI inflation falls. The reason for the weak international responses of prices might be due to two sources, namely a general increase in inflation due to excessive capital inflows and a sharp increase in global liquidity and on the other hand tighter capital control measures to shield regions (especially Asia) against inflationary developments.



Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 3: Inflation reactions

Looking at the responses of exchange rates reveals that demand shocks generate

a rather heterogeneous pattern of responses across regions.[27] Across all regions considered, we find strong reactions of European real exchange rates, with exchange rate movements in other regions being more modest. Specifically, Figure 4 indicates that European currencies depreciate vis-á-vis the US dollar. The heterogeneous impact on the real exchange rate across countries and regions might be driven by the rather loose identification scheme adopted, where we assume that real exchange rates depreciate on average, as opposed to the restriction that all countries display a depreciation on impact.

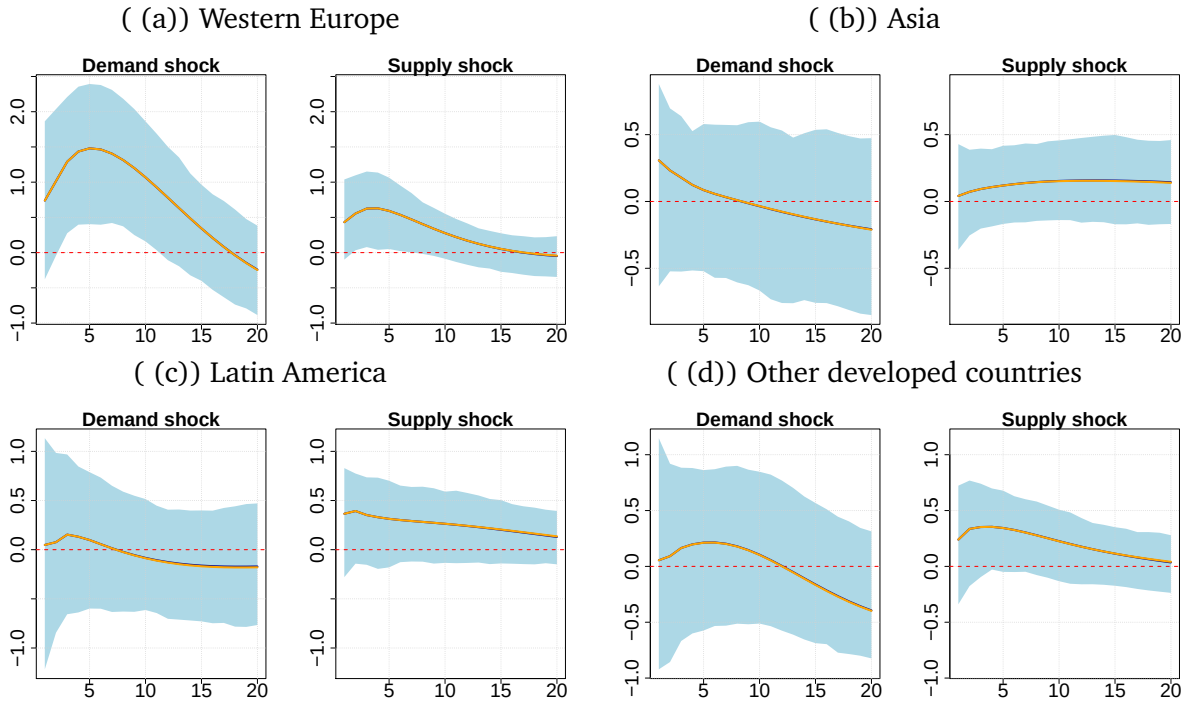
Exchange rate responses to demand shocks are rather short lived. One possible explanation is that monetary policy authorities in some emerging market economies fear large and volatile capital inflows, therefore they lower the policy rate quickly with the aim to prevent the exchange rate to appreciate. Indeed, Gourinchas and Obstfeld (2012) show that a surge in capital inflows lead to strong exchange rates fluctuations that are capable of pushing the country into a financial crisis in the event of a sudden stop, making macroeconomic policy more difficult.

Similarly to the demand shock, a positive increase in the supply of safe assets also leads to a depreciation of European real exchange rates against the dollar. Consequently, it appears that a shortage in safe assets due to a shrinking supply translates into an exchange rate appreciation as noted in Caballero, Farhi, and Gourinchas (2016), (see Figure 4).

Demand shocks generate an initial negative response of short term interest rates in Western Europe and Latin America, followed by a persistent increase (see Figure 5). For other developed countries, we find considerable evidence of a long-lasting increase in the interest rate over 20 quarters, while responses in Asia and Latin America prove to be surrounded by large estimation uncertainty mostly. Supply shocks have a limited impact on short-term interest rates. Indeed, Caballero, Farhi, and Gourinchas (2016) shows that when the ZLB is reached, the international transmission of shocks mainly occurs via the exchange rate and global output channel. While our responses indicate that this also happens if US interest rates are allowed to vary freely, we would like to stress that policy responses in the US are small under the baseline scenario. Thus, even if the ZLB is not reached the transmission tends to happen through output and exchange rate spillovers.

The response of the risk spread is depicted in Figure 6. Risk spreads decrease on impact to a one standard deviation positive demand shock in Western Europe and other developed economies by around 12 basis points. Quantitatively, supply

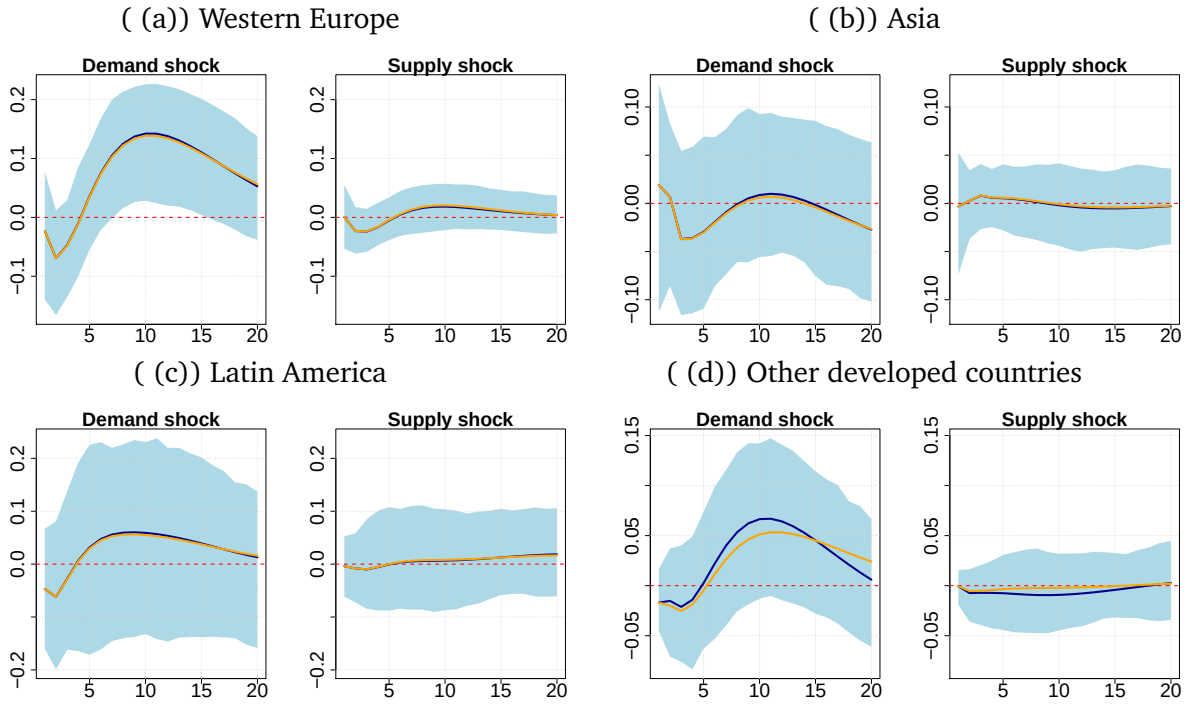
[27]The figure reports the exchange rate expressed as the foreign value of the dollar. Therefore, a decrease in the exchange rate implies an appreciation of the foreign currency against the dollar.



Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 4: Exchange rate reactions

shocks have a weaker negative impact on the risk spread, with countries located in Western Europe and the other developed countries group displaying a decline of around 2.5 basis points measured by the median response. This indicates that the risk spread is mainly driven by demand shocks, implying that US investors require a lower risk premium to invest in foreign assets. The increase in the perceived safety of foreign assets encourages US investors to reallocate parts of their capital from domestic assets into foreign assets. Moreover, the ZLB and unconventional monetary policy reduced the availability of safe assets for US investors, increasing the share allocated to foreign assets in the US bond portfolio. Similar findings are found in Burger, Sengupta, Warnock, and Warnock (2015). They show that global push factors such as low US long-term interest rates and quantitative easing policies encourage the re-allocation of international bond portfolios of US investors, who increasingly invested in emerging markets local currency bonds. Differently from Burger, Sengupta, Warnock, and Warnock (2015), we find a weak reaction of risk spreads in emerging

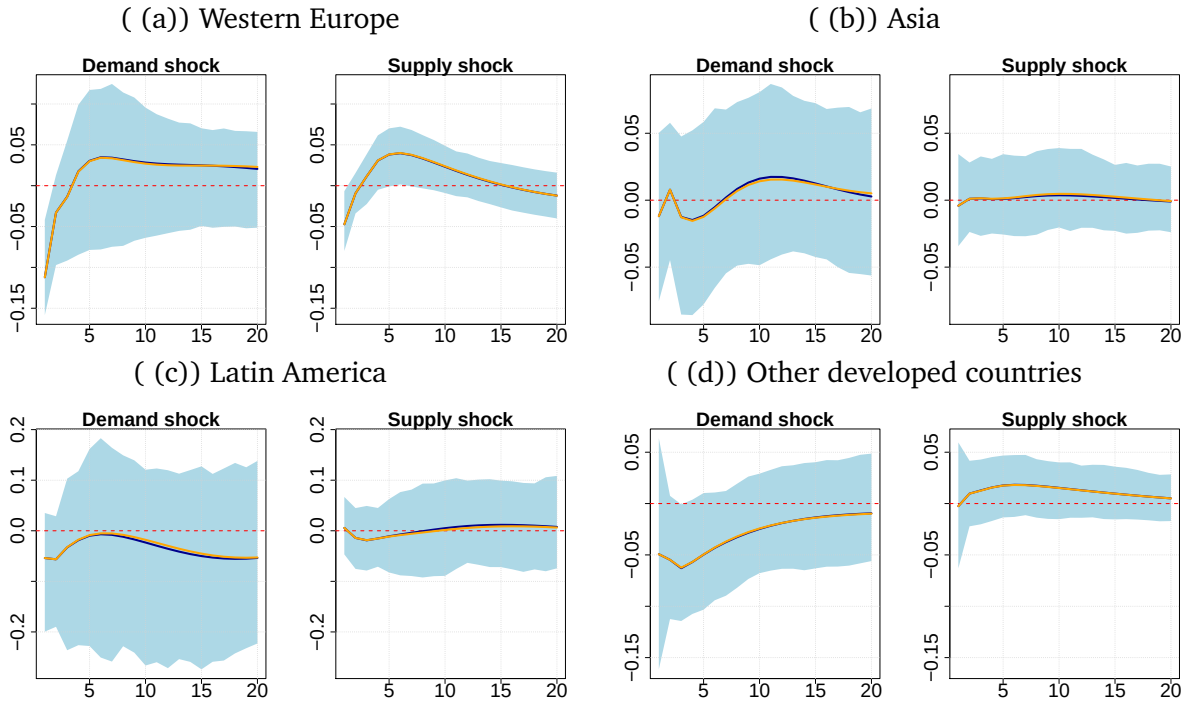


Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 5: Short-term interest rate reactions

market economies because our study focuses on the overall bonds acquired by US residents in dollar-denominated assets, rather than local currency assets.

Equity prices respond positively to a one standard deviation positive demand shock in the majority of countries in our sample (shown in Figure 7). The reaction is elevated in the majority of countries, with equity prices increasing by about one percent on average, with a stronger reaction in Western Europe. There, equity prices increase by over two percent on average after one year. For three out of the four regional averages, we find that the positive reactions of equity prices last for at least two years. This corroborates findings in Shin (2012), Mendicino and Punzi (2014), Punzi and Kauko (2015) and Sá and Wieladek (2015) who show that capital inflows lead to asset price booms in the receiving country. In particular, the low yield on US assets lead US investors to search for yield, inflating asset prices in foreign countries. By contrast, reactions of equity prices to a supply based shock turn out to be insignificant, suggesting that the effects appear to be significantly weaker as compared to demand-sided

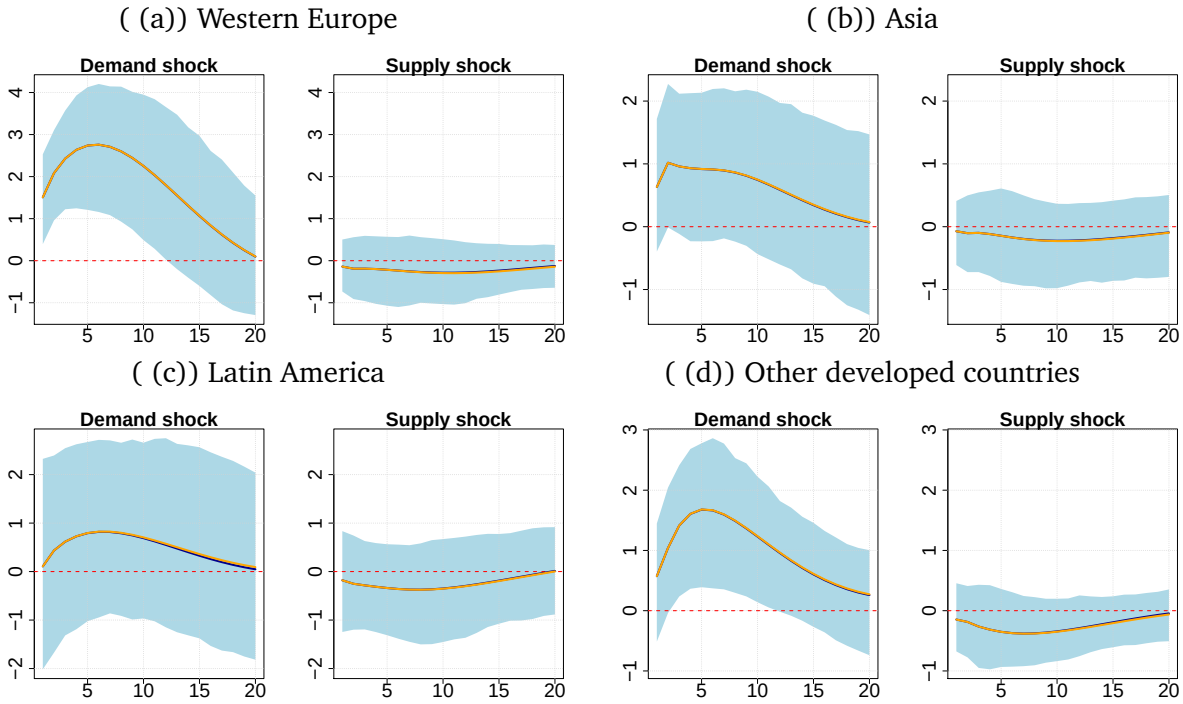


Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 6: Risk premium reactions

shocks.

Figure 8 reports impulse responses to demand and supply shock on claims, representing the preferences of US investors for foreign assets. The increasing demand of US safe assets leads to a drop in US holdings of foreign assets from all regions. On the other hand, positive supply shocks lead to a decrease in the US holdings of foreign assets. Across regions, the decrease is persistent and about 0.5 percent, meaning that the scarcity of US safe assets implies a stronger preference of US investors towards foreign assets. This result is consistent with the findings in Bertaut, Tabova, and Wong (2014), who report a strong negative correlation between the foreign share of the US financial bond portfolio and the availability of US safe assets, providing evidence on the expansion of the foreign financial sector, which has met the increasing US demand for safe and liquid investment assets by expanding its supply. Bertaut, Tabova, and Wong (2014) highlight the strong substitution effect between scarce US safe assets and foreign-issued financial sector debt that appeared after the crisis.

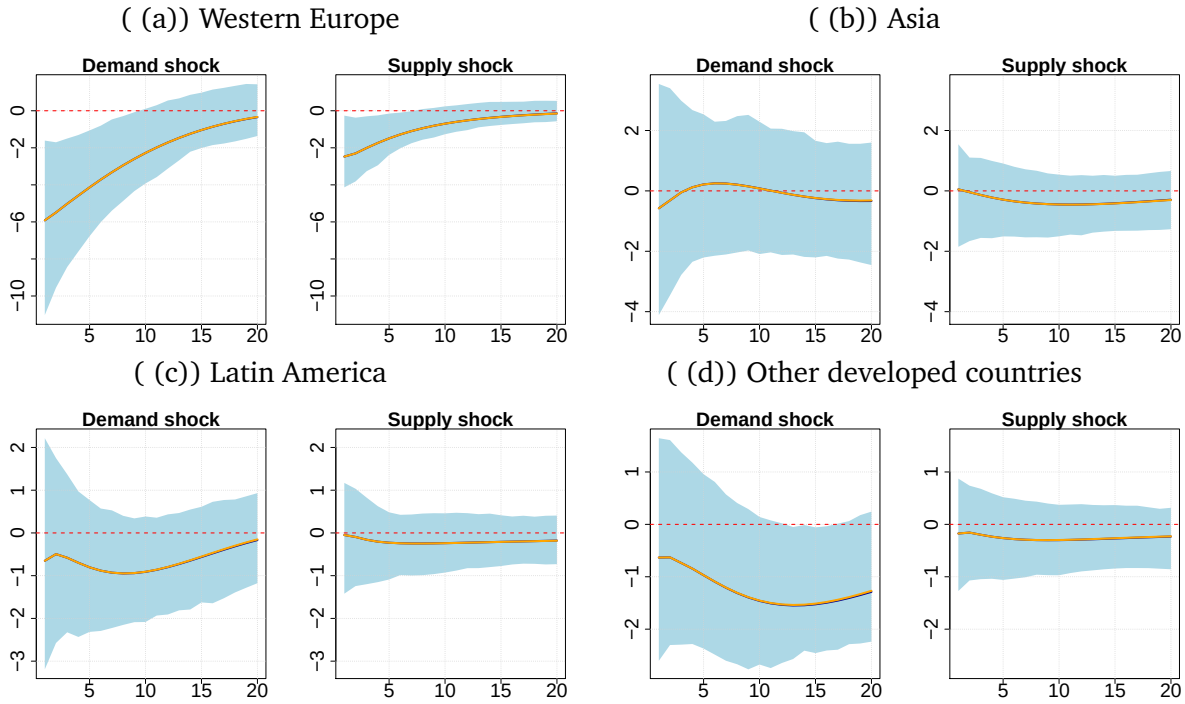


Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 7: Equity price reactions

During the crisis, the US supplied safe assets via the US FED swap lines extended to the ECB and several other selected central banks in order to provide them dollar liquidity. The FED thereby acted as a global lender of last resort for dollars. We also control for this stylized fact by including US swap lines in our modeling framework. We find that both, demand and supply shocks only exert weak effects on swap lines, meaning that the decision of offering swap lines by the US Fed is not driven by the shortage of safe assets or domestic fundamentals (see Figure 9). Indeed, Allen, Moessner, et al. (2010) found that the US supply of swap lines during the post-crisis period was statistically significantly larger for economies with higher US dollar shortages and with larger international financial centres.

The results presented hitherto have been based on regional averages and thus neglect intra-group heterogeneity. Therefore, we avoided talking about statistical significance up to this point, only referring to statistically robust relations if the posterior distribution of the averaged impulse responses does not contain zero or by cross-

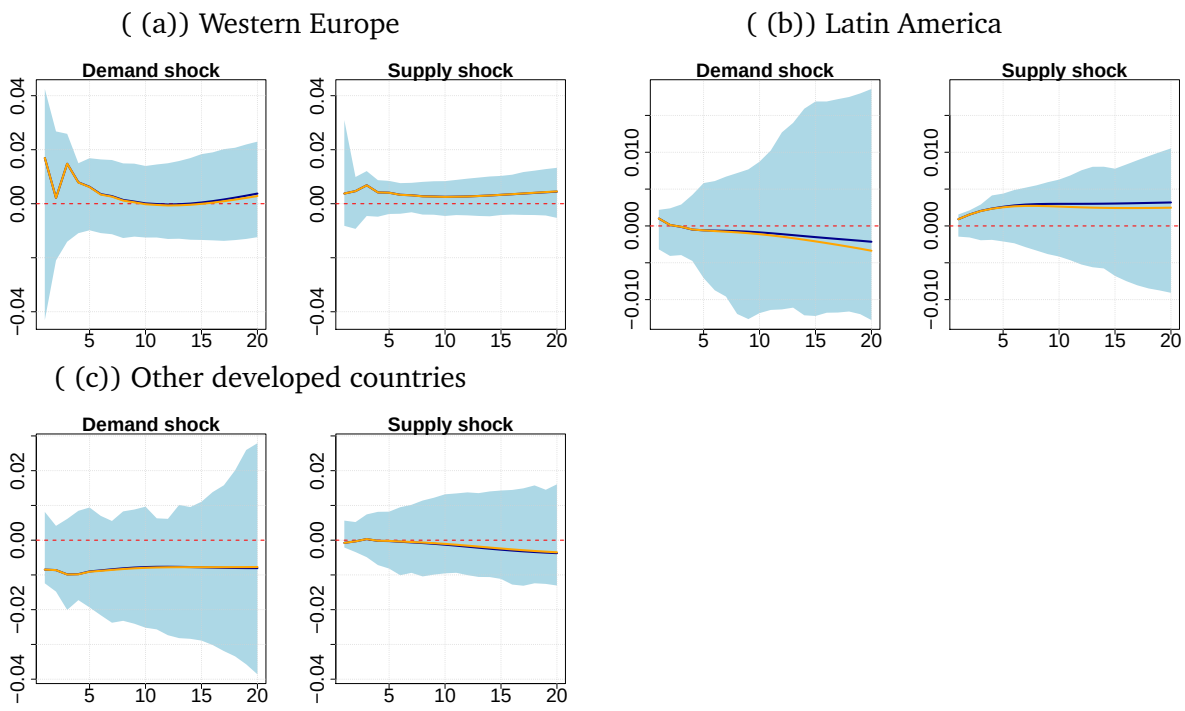


Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

Figure 8: Claims reactions

checking whether individual countries within a group feature significant responses. However, even if the average posterior distribution contains zero, it could be the case that the responses are actually significant at the country level. To see this, note that if two countries display the same (statistically) significant reaction in terms of magnitudes but with opposing signs the average posterior response will certainly contain zero. Thus, to provide some information on cross-country heterogeneity, we report boxplots showing the peak response (positive and negative) of a given variable with respect to safe asset demand and supply shocks for a set of selected countries. The whiskers of the boxplots indicate whether a given response is significant and offer information on the uncertainty surrounding the estimates, while the level of the bar gives information on the size of the peak effect. Thus, if the red intervals include zero the effect is statistically insignificant.

Figure 10 and Figure 11 report the peak effects at country level for a demand and supply shock, respectively. These figures show that the peaks are higher for a demand



Notes: Posterior distribution of impulse responses averaged across countries. Median in black. Dotted blue lines correspond to the 25th and 75th percentiles. Results are based on 35,000 posterior draws. The red line indicates the zero line and the orange line depicts the impulse responses obtained by imposing the zero lower bound constraint.

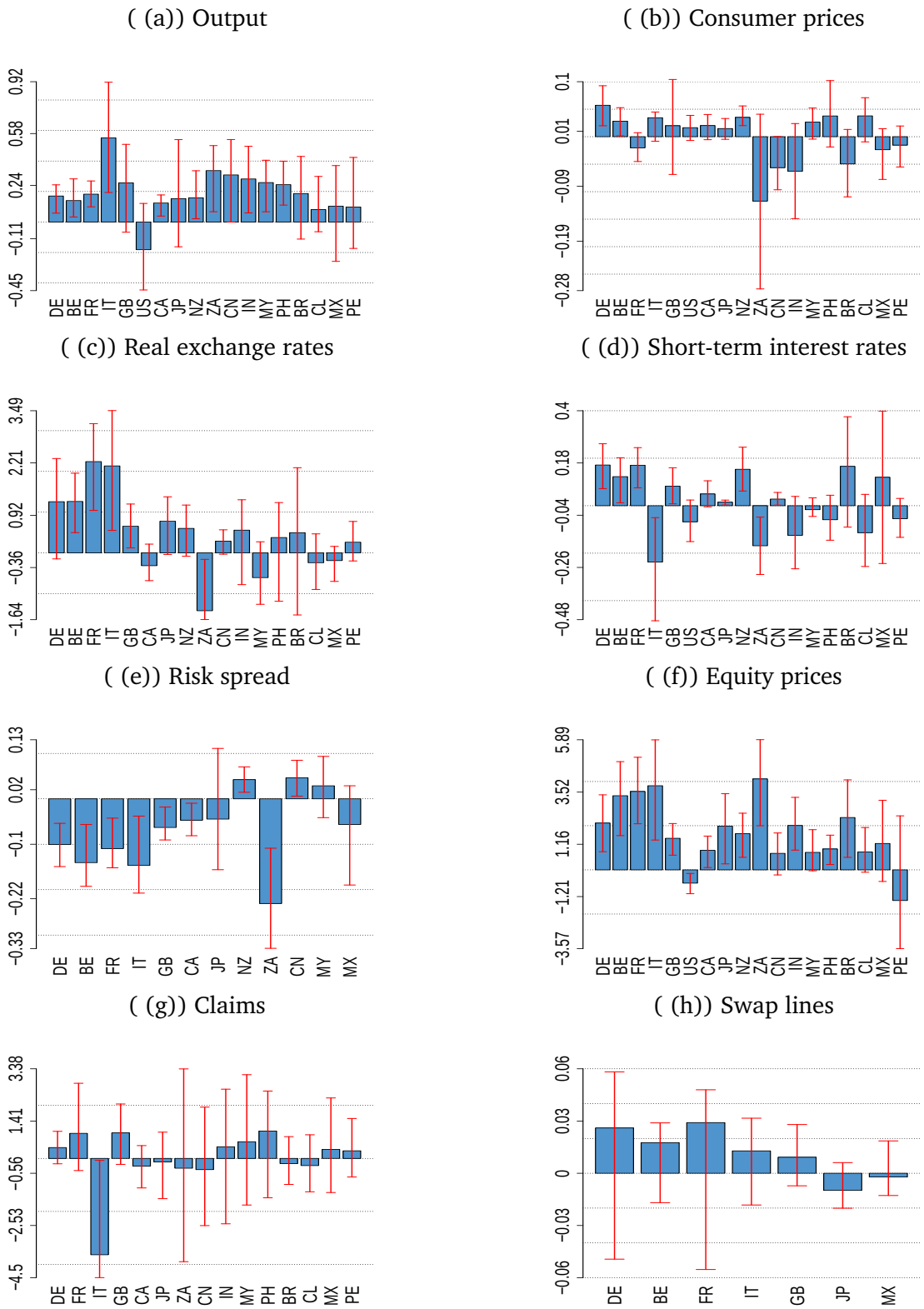
Figure 9: Swap line reactions

shock rather than a supply shock.

In general, and for both shocks, we find that for output, equity prices and short-term interest rates, the overall pattern described above in the case of the IRFs are confirmed by looking at the posterior distribution of the peak response. For most economies under consideration, we see statistically significant peak effects. Note that for short-term interest rates, some countries display an significant peak increase (mostly countries located in Western Europe except Italy) whereas some other economies typically feature negative responses of interest rates. This conclusion also carries over to the real exchange rate, where the majority of currencies under scrutiny react by depreciating relative to the US dollar with some notable exceptions (for instance, South Africa).

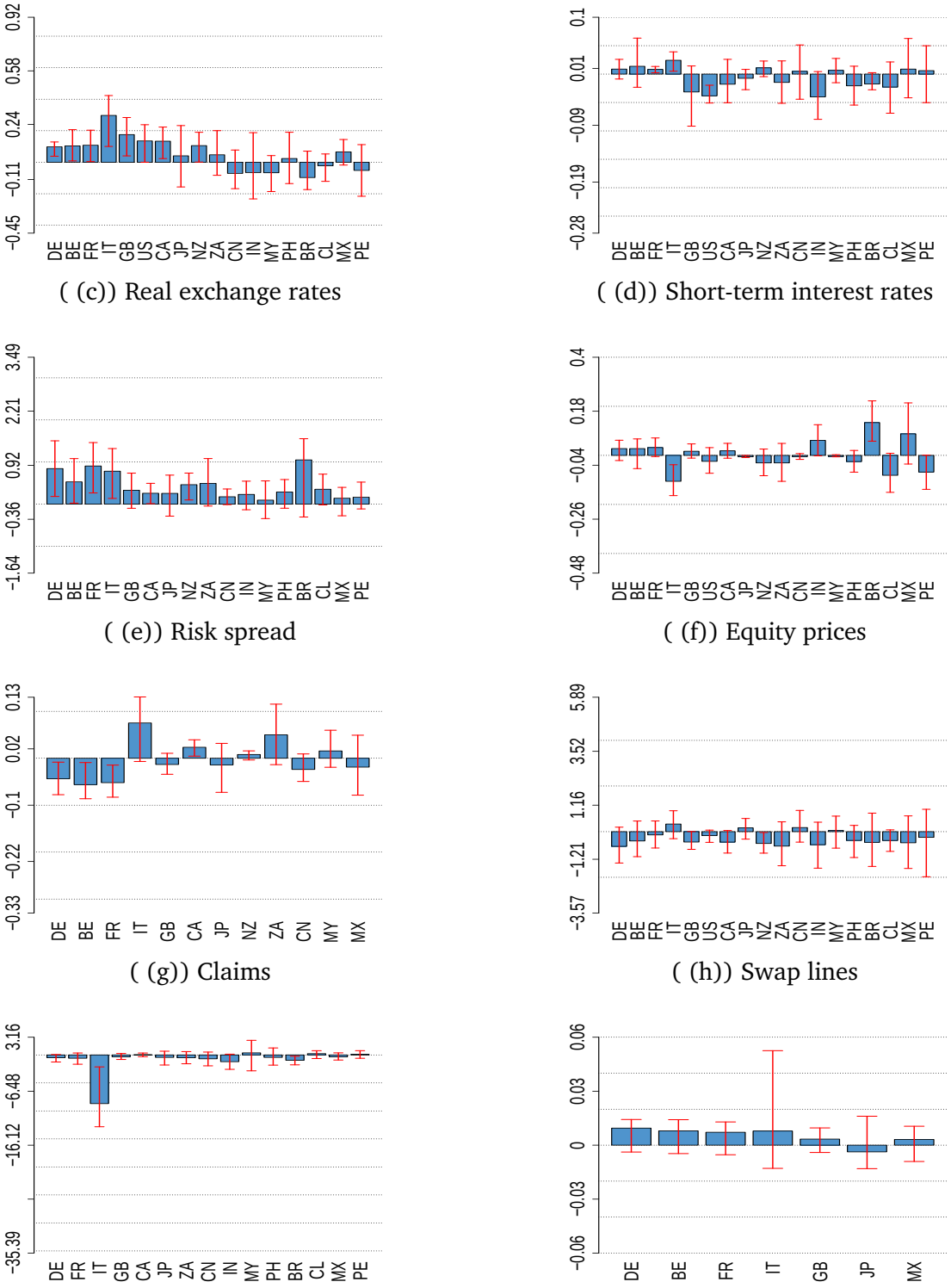
Responses of the risk spread to a demand shock are quite homogeneous across countries, dropping on average by around ten to 15 basis points. This finding, however, does not carry over to the supply-based shock. There we find mixed responses,

Figure 10: Peak effects of spillovers (aggregate demand shock)



Notes: The bar plots show peak effects in absolute terms with the whiskers denoting 50% credible intervals. A decrease of the exchange rate response implies an appreciation of the local currency against the US dollar.

Figure 11: Peak effects of spillovers (aggregate supply shock)



Notes: The bar plots show peak effects in absolute terms with the whiskers denoting 50% credible intervals. A decrease of the exchange rate response implies an appreciation of the local currency against the US dollar.

with countries in Western Europe mostly experiencing declines in their risk premia whereas other countries like Canada face increasing risk spreads. While we see that other countries do not react in a significant fashion, one finding stands out. The vast majority of posterior mass of peak responses is concentrated above zero in the case of a supply shock, indicating that there seems to be some upward pressure on risk spreads in certain countries located outside of Europe.

Viewing these findings in light of the results presented for the impulse responses suggests that the excess global demand for US safe assets spills over to foreign countries through the exchange rate and liquidity channel, while the insufficient supply of US safe assets leads to a portfolio re-balance, as US investor search for yield.

6. Conclusive remarks

In this paper we investigate the international consequences of the shortage in US safe assets. By adopting an empirical macroeconomic framework, that jointly models a large set of economies under consideration, we explore the international transmission of supply and demand shocks to US safe assets. We estimate a Bayesian variant of the Global VAR (GVAR) model coupled with stochastic volatility over the period 1994 to 2014 at quarterly frequency and consider 34 countries. To identify supply shocks, we update data from Gorton, Lewellen, and Metrick (2012) until 2015. Their measure is constructed as the sum of US government debt and the safe component of private financial debt. On the demand side, we use US international liabilities from Bertaut and Tryon (2007) and Bertaut and Judson (2014).

Our findings indicate that decreasing supply of US safe assets leads to a decline in US output, pushing the country towards a recession. At the international level, this effect spills over to other countries and foreign output also tends to fall, as predicted in Caballero, Farhi, and Gourinchas (2015) and Caballero, Farhi, and Gourinchas (2016). The shrinking supply of US assets lead US investors to search for investment opportunities abroad. However, we would like to stress that this finding only holds for a relatively limited set of countries in our dataset. On the other hand, we find sizable macroeconomic effects of demand-sided shocks. The continuing foreign preferences for US safe and liquid assets leads to persistent output increases and to a rather short-lived decrease in the volatility index VIX. Financial markets, in general, tend to profit from both shocks, displaying increases in equity prices for a large number of countries considered. Internationally, foreign countries experience strong capital inflows stemming from the US. Such surge in foreign funding affects foreign output in a positive fashion and leads to pronounced increases in equity prices. Interest rates in foreign economies tend to decrease in order to avoid adverse effect on the home countries'

currency.

These results point towards different channels through which supply and demand shocks feed into the global economy. We find that supply shocks spread globally through portfolio re-balancing, while demand shocks impact the global economy through the exchange rate and liquidity channel. Moreover, we find that demand shocks definitely exert a much stronger impact on the US and the global economy.

Given the importance of the research question, it is of prime importance to derive policy implications. Since both, insufficient supply and excess global demand for US safe assets exerts downward pressure on interest rates, US investors are forced into more risky domestic assets (during the pre-crisis period) and into foreign assets (after the global financial crisis engulfed the world economy). Our findings indicate that decreases in the supply of US safe assets has the potential to push the global economy into a recession, making it necessary for US policy makers to consider supplying more safe assets in order to avoid future recessions and circumvent price bubbles elsewhere. Moreover, issuing more safe assets seems to exhibit inflationary pressure on the economy. At the international level, several countries have become increasingly innovative in designing assets that may be viewed is relatively risk free, thus providing their own safe assets, attracting even more US investors. However, creating new safe asset markets could lead to excess capital inflows, making it necessary for foreign countries to implement capital controls. In addition, our findings, at least to some extent, suggest that foreign central banks react to exchange rate pressure by lowering their policy rates. The introduction of further capital control measures could thus help to regain monetary policy independence.

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