The Impact of US Financial Uncertainty Shocks on Emerging Market Economies: An International Credit Channel*

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Abstract

I document that US financial uncertainty shocks, measured by an increase in VIX, have a substantial impact on the output of emerging market economies (EMEs) without a material impact on US output during the last two decades. To understand this puzzling phenomenon, I propose a credit channel as a propagation mechanism of US financial uncertainty shocks to EMEs. I augment a boom-bust cycle model of EMEs by Schneider and Tornell [2004] with a portfolio choice model of constrained international investors. As international investors pull their money from EMEs—to satisfy their Value-at-Risk constraints—in response to financial uncertainty shocks, borrowing costs increase and domestic credit contracts. Higher borrowing costs and a decline in domestic credit, in turn, lead to a fall in investment in the non-tradable sector that causes a real depreciation via currency mismatch prevalent in EMEs and a decline in total output through sectoral linkages. The empirical regularity obtained by estimating structural VARs of 18 EMEs is consistent with the prediction of the model.

Keywords: Uncertainty shocks; Emerging market economies; Credit channel; Vector Autoregressions; Portfolio choice model; Value-at-Risk constraint

JEL Classification: E30; F30; G10

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1 Introduction

This paper examines the impact of US financial uncertainty shocks, measured by VIX,[1] on emerging market economies (EMEs). Structural Vector Autoregressions (VARs) derived from an equilibrium model are estimated using data from 18 EMEs over a period from January 1994 to December 2013. From the structural VARs, I find that US financial uncertainty shocks have a substantial impact on the output of EMEs, but they do not have a significant impact on US output. Figure 1 presents the evidence for this claim.[2] This new empirical finding highlights a fundamental difference between EMEs and the US economy, which is key to understanding volatile business cycles in EMEs.

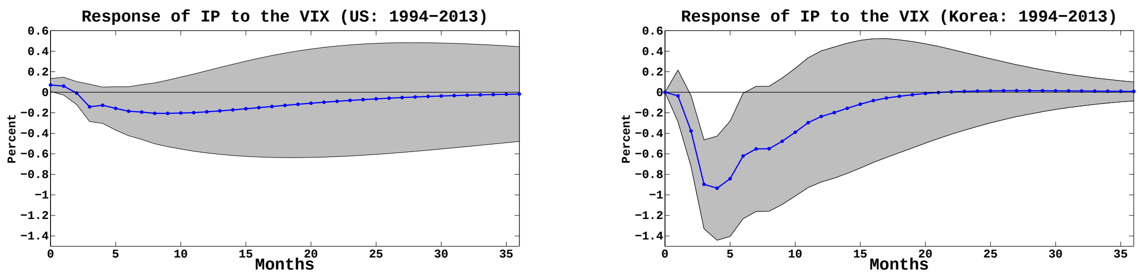

Figure 1: Output responses to US financial uncertainty shocks

Notes: This figure plots the response of industrial production of the US (left) and Korea (right) between January 1994 and December 2013 to a one standard deviation shock to VIX in the bivariate VARs using VIX and the log of industrial production. The shaded areas are 90% bootstrap confidence interval.

To explain the contrasting impact of US financial uncertainty shocks on EMEs from their impact on the US economy, I interpret VIX as a measure of risk appetite that captures international investors' preference for safe assets when facing heightened uncertainty. In the model, a stronger preference for safe assets translates into higher borrowing costs in EMEs via credit market imperfections. As a result, tighter constraints on borrowing in EMEs lead to a fall in investment, which in turn, results in a real depreciation and a decline in total output through sectoral linkages. I propose

[1] VIX is a measure of market expectations of near-term volatility, as implied by S&P 500 stock index option prices, which becomes a standard measure of uncertainty in financial markets. Here, I distinguish financial uncertainty from uncertainty regarding other dimensions of the economy, such as economic policy uncertainty by Baker et al. [2016] and focus on the former. The recent episodes of the Brexit and the US presidential election demonstrate how empirical proxies for each uncertainty can diverge dramatically from one another.

[2] Seeking the most parsimonious means of representation, the VAR model used here only includes the level of VIX and the log level of industrial production without de-trending, as described in Bachmann et al. [2013]. VIX is ordered first in a recursive identification, and the VARs are estimated with six lags. However, the insignificant impact of financial uncertainty shocks on US output found in this paper is not driven by different identifying assumptions from an influential paper by Bloom [2009]. By using the same identifying assumptions from Bloom [2009], Choi [2013] finds that the impact of (financial) uncertainty shocks on US output and employment has substantially decreased since the mid-1980s. I still obtain a strong impact of an increase in VIX on US output from estimating the same bivariate VARs for an earlier period. See Section A.3.1 in the online appendix for further evidence.

that this credit channel serves as a propagation mechanism of US financial uncertainty shocks to EMEs, and that it is distinct from the "wait-and-see" mechanism proposed by Bloom [2009]. To the extent to which investments in EME assets are risky, the asymmetric effects between the US economy and EMEs are consistent with a property of VIX: Bekaert et al. [2013] decompose VIX into risk aversion and uncertainty components and find that the former is particularly related to risk-taking behaviors in financial markets.[3]

The model consists of two parts: an international asset market and an emerging market domestic economy. International investors allocate their wealth across three types of assets: (i) safe assets (e.g., US Treasury bills), (ii) risky assets from the US economy (e.g., US stocks), and (iii) risky assets from EMEs (e.g., emerging market bonds). US financial markets are particular interest of the model given their special role to provide liquidity and safe assets to the world and the distinguished role of the dollar as an investing currency and funding currency (Rey [2015]). To understand an international spillover of uncertainty shocks from the US financial market to EMEs, I assume that international investors are subject to a Value-at-Risk (VaR) constraint under which the expected loss should meet a predetermined VaR limit (Borio and Zhu [2012]; Adrian and Shin [2014]).

To model the emerging market domestic economy, I build on a boom-bust cycle model of Schneider and Tornell [2004] featuring credit market imperfections in EMEs. The emerging market domestic economy consists of two sectors: tradable and non-tradable. I model firms in the non-tradable sector as borrowing-constrained. Non-tradable sector firms can only borrow from domestic banks, and their borrowing is limited by their net worth due to contract enforceability problems. Domestic banks take on currency mismatch by borrowing in tradable goods from international investors and lending to non-tradable sector firms. These loans are denominated in units of non-tradable goods.[4] The realization of low productivity triggers a real depreciation because demand for non-tradable goods as an input of the tradable sector production decreases. With currency mismatch, the real depreciation leads domestic banks to default on their bonds. International investors diversify this risk by investing in a large number of symmetric countries.

For this study, I model the US financial uncertainty shock as an increase in the conditional variance of returns on US stocks, as close as possible to its empirical measure (VIX). Under the VaR constraint, US financial uncertainty shocks encourage interna-

[3] I thank to the anonymous referee for his suggestions on linking the risk aversion interpretation of VIX in this paper to Bekaert et al. [2013].

[4] This setup is intended to capture a common practice in EMEs where banks borrow in dollars and lend in local currencies (e.g., pesos).

tional investors to reduce their demand for emerging market risky assets, so as to limit their downside risk (as in the case of a risk-aversion shock). As the supply of emerging market bonds remains the same, US financial uncertainty shocks trigger an increase in the external cost of financing by domestic banks, which in turn, translates into more binding borrowing constraints at each level of a non-tradable sector firm's net worth. Having less credit, non-tradable sector firms invest less, leading to a real depreciation through the market-clearing condition for non-tradable goods.[5] Although tradable sector firms are not financially constrained, sectoral linkages lead to a fall in total output.

I derive structural VARs from the recursive equilibrium of the model and estimate them with data from 18 EMEs. The following three facts characterize the main results. First, on average, each country's borrowing spreads—the difference between real domestic lending rates[6] and the real risk-free rate (i.e., 3-month T-bill rates)—increase by 0.3% points and real domestic credit to the private sector declines by 0.5% following a one standard deviation shock to VIX. Second, real effective exchange rates depreciate by 0.7%. Third, domestic output—measured by industrial production—declines by 0.7%. The fall in domestic credit and the increase in borrowing spreads for each economy indicate that US financial uncertainty shocks act as an exogenous credit supply shock to EMEs.

In contrast to the sample EMEs, the US economy shows sharply different responses to US financial uncertainty shocks. Following US financial uncertainty shocks in a similarly-identified structural VAR model, the risk-free real interest rate falls by 0.07% points, the real effective exchange rate appreciates by 0.4%, real domestic credit increases by 0.3%, and industrial production decreases only by 0.1%. Further, the fall in industrial production is statistically insignificant.

2 Related literature

This paper contributes to three strands of literature. First, I highlight the fundamental difference between the US and EMEs, thereby providing explanation on the recent empirical findings that US financial uncertainty shocks have substantial effects on real activity in EMEs (Matsumoto [2011]; Akıncı [2013]; Carrière-Swallow and Céspedes [2013]). Whereas previous studies evaluate the effects of US financial uncertainty shocks on emerging market financial variables, such as sovereign spreads (González-Rozada and Yeyati [2008]) or exchange rates (De Bock and de Carvalho Filho [2015]), they do not

[5]While the supply of non-tradable goods is predetermined—i.e., fixed in the current period—the demand for them decreases. To clear the market, the price of non-tradable goods falls, which leads to real depreciation (because the price of tradable goods is internationally given).

[6]Real domestic lending rates are measured by the difference between nominal domestic bank lending rates and expected inflation rates. See Section A.1.1 in the online appendix for how to measure expected inflation rates.

provide a unified theoretical framework to understand how these financial variables interact with the real economy. I have sought to provide an integrated framework allowing for such study both theoretically and empirically.

The propagation mechanism of US financial uncertainty shocks in this paper shares implications from existing studies. For example, the importance of financial frictions as an amplifying mechanism of uncertainty shock is highlighted in Christiano et al. [2014] and Choi et al. [Forthcoming] among others. As in Gourio [2012], an increase in US financial uncertainty leads risk-averse investors to invest less in risky assets. The market segmentation between safe and risky assets in Matsumoto [2011] resembles the interpretation in this paper of an international asset market. The credit channel as a propagation mechanism of US financial uncertainty shocks in EMEs is similar to that in Carrière-Swallow and Céspedes [2013] who find that the effects of US financial uncertainty shocks on investment and consumption in EMEs are substantially larger than those in advanced economies.

Second, the empirical results from this paper shed light on the sources of volatile emerging market business cycles. On one hand, recent international Real Business Cycle (RBC) literature, such as Neumeyer and Perri [2005] and Uribe and Yue [2006] concludes that volatile and counter-cyclical real interest rates in EMEs are the key to understanding their distinct business cycle fluctuations. This paper shows that uncertainty in US financial markets can be a source of counter-cyclical interest rates independent of the real side of the US economy (e.g., US productivity shocks). On the other hand, financing asymmetry between the tradable and the non-tradable sectors prevalent in EMEs has been another explanation for their boom-bust cycles (Caballero and Krishnamurthy [2001]; Schneider and Tornell [2004]). This paper connects with the above studies by linking US financial uncertainty shocks to a balance-sheet effect in EMEs via the financing asymmetry between the two sectors.

Finally, the introduction of the VaR constraint as a propagation mechanism of US financial uncertainty shocks resembles prior works in the financial contagion literature that emphasize regulations or risk management practices (e.g., borrowing constraints, VaR constraints, margin requirements, and collateral constraints) as a source of the transmission of a financial crisis in one country to other economies without parallel deterioration in their fundamentals (Kaminsky and Reinhart [2000]; Kyle and Xiong [2001]; Pavlova and Rigobon [2008]). The risk appetite (or risk aversion) interpretation in this paper is an outcome of the constrained maximization problem of international investors similar to Schinasi and Smith [2000]. Schinasi and Smith [2000] show how an increase in volatility of returns on one risky asset can reduce the demand for other risky assets through the VaR constraint.

3 Model

I develop an equilibrium model in which there are two types of shock: US financial uncertainty shocks and aggregate productivity shocks. The emerging market domestic economy consists of two sectors: tradable and non-tradable. The two-sector setup is required to understand the synchronized depreciation of EME exchange rates and spikes in VIX found in the literature (for example, De Bock and de Carvalho Filho [2015]). Focusing on the EMEs' institutional features that are distinct from those of the US economy, I introduce credit market imperfections to the model following the framework of Schneider and Tornell [2004]. The model consists of four agents: non-tradable sector firms that are run by an overlapping generation of managers; tradable sector firms; domestic banks; and international investors. Figure 2 summarizes the key components of the model.[7]

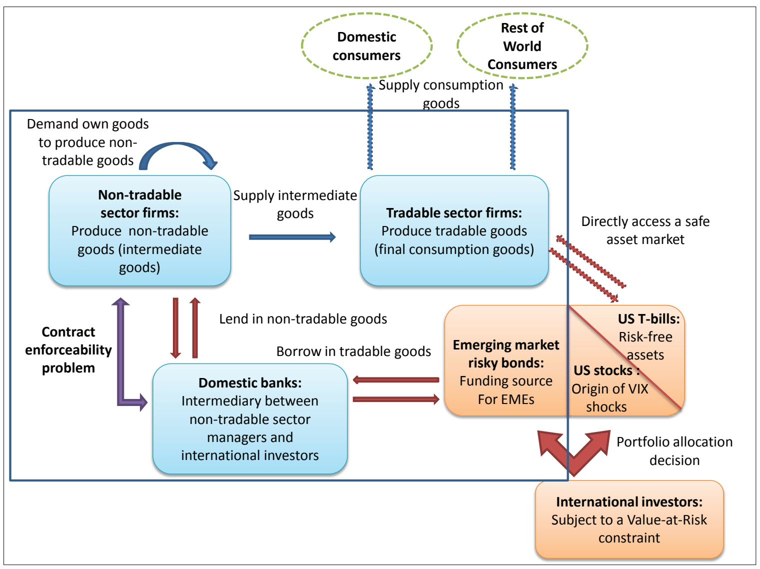

Figure 2: Flowchart of the model

3.1 Domestic economy

A tradable sector firm produces final consumption goods, and a non-tradable sector firm produces intermediate goods that are used as an input in the production of the tradable and the non-tradable sector. Using tradable goods as the numeraire, I denote the inverse of the real exchange rate by $p_t = \frac{p_t^N}{p_t^T}$, where p_t^N is the price of non-tradable goods and p_t^T is the price of tradable goods. The price of tradable goods is

[7] I do not specify the problems of consumers (denoted by dashed circles in Figure 2) in the model. As the economy is small and open, the destination of tradable goods is not important for the main implication of the model.

internationally fixed, so the price of non-tradable goods determines the real exchange rate.

Tradable sector firms

Tradable sector firms produce tradable goods by using a non-tradable sector input d_t and labor l_t, according to the following production function:

$$y_t^T = a_t d_t^{\alpha} l_t^{1-\alpha}, \tag{1}$$

where a_t is a binomial aggregate productivity shock, l_t is labor, and $\alpha \in (0,1)$. For simplicity, I assume that supply of labor is inelastic, so $l_t = 1$ for every period.

There are two states (good, bad) for the realization of the aggregate productivity shock in the tradable sector: a and 0, with the respective associated probabilities of $1-u$ and u.[8]

$$a_t = \begin{cases} a \text{ with a probability } 1-u \\ 0 \text{ with a probability } \quad u \end{cases}$$

To ensure that the borrowing constraints of non-tradable sector firms always bind in equilibrium, the productivity of the tradable sector a_t is expected to shift in the finite future ($t = T$), following Schneider and Tornell [2004].[9]

$$a_t = \begin{cases} a \text{ or } 0 & \text{if } \ t < T \\ \quad \bar{a} & \text{if } \ t = T, \end{cases}$$

where $a < \bar{a}$.

Non-tradable sector firms

Non-tradable sector firms are run by dynasties of managers who live through two periods. Non-tradable goods are produced using a non-tradable good as an input I_t, according to the following linear technology:

$$y_{t+1}^N = \theta I_t, \tag{2}$$

where θ is productivity of the non-tradable sector.

The investable funds of a non-tradable sector firm consist of the one-period loan (from a domestic bank), which is denominated in non-tradable goods—worth a total of b_t units of tradable goods—plus the firm's net worth n_t in tradable goods. Therefore, the non-tradable sector firm's budget constraint at time t, measured in tradable goods,

[8]The zero productivity in the bad state is just for simplicity, and any productivity lower than a would work as well.

[9]A large enough productivity shift in the final period induces a substantial real appreciation, encouraging non-tradable sector firms to take more debt along the equilibrium path.

is:

$$p_t I_t = n_t + b_t. \tag{3}$$

The time-t young manager inherits a net worth position n_t from her predecessor, and borrows b_t units of tradable goods by taking the non-tradable goods debt from a domestic bank. She promises to repay $(1 + i_t^D)b_t$ units of non-tradable goods at time $t+1$, where i_t^D is the real lending rate that the domestic bank charges on the manager. At the end of the period t, the time-t old manager sells non-tradable goods and repays her debt from the previous period. Therefore, her profit in terms of tradable goods is

$$\pi_t(p_t) = p_t y_t^N - p_t(1 + i_{t-1}^D)b_{t-1}. \tag{4}$$

The time-t old manager distributes a fraction β of the profit (if positive) as a dividend to herself and passes on the rest $(1-\beta)\pi_t(p_t)$ to her successor (time-t+1 young manager):

$$n_{t+1} = (1 - \beta)\pi_t(p_t). \tag{5}$$

When a non-tradable sector firm becomes insolvent ($\pi_t(p_t) < 0$), all the revenue that the firm produces will dissipate, and a time-$t+1$ young manager receives a small amount of government aid ϵ to start up. This situation, however, will not occur in equilibrium, as non-tradable sector firms find it optimal to hedge real exchange rate risks by borrowing in non-tradable goods only.

Domestic banks

Domestic banks specialize in intermediating funds from international investors to non-tradable sector managers through an emerging bond market. There are measure one of risk-neutral and competitive domestic banks. At period t, a domestic bank borrows from an emerging bond market by selling bonds at the price q_t, with the promise to repay one unit of tradable goods in the period $t+1$, and then lends the borrowed funds to managers in non-tradable goods (i.e., they take on currency mismatch).

If the bank defaults on these bonds, international investors only collect Δ units of tradable goods per each unit of bonds purchased. For simplicity, I set $\Delta = 0$, so that emerging market bonds become completely worthless in the case of default, and defaulted banks are replaced by new banks. The emerging market bond price q_t

determines the external cost of borrowing i_t faced by the domestic banks.[10]

$$1 + i_t \equiv \frac{1-u}{q_t}. \tag{6}$$

3.2 International asset market

International investors

An international asset market is inhabited by a large number of identical two-period lived investors who will be represented by a representative investor. In period t, the representative investor is born with her exogenous wealth W_t in tradable goods, and maximizes the one-period expected returns from her portfolio investment. Her maximization problem is subject to the VaR constraint. The representative investor solves the following problem:

$$\max E_t R^P_{t+1}, \tag{7}$$

subject to

$$prob\Big(R^P_{t+1} < \underline{R}\Big) \leq \gamma, \tag{8}$$

where R^p_{t+1} is the one-period gross rate of returns from the representative investor's portfolio. The VaR constraint (8) states that there is at most a γ percent chance of incurring losses that exceed $(1-\underline{R})W_t$ between t and $t+1$.

Under the joint normal distribution of perceived asset returns, which will be derived shortly, the constraint (8) can be written as

$$E_t R^P_{t+1} \geq \underline{R} + \Phi(1-\gamma)\sqrt{Var_t R^P_{t+1}}, \tag{9}$$

where Φ denotes the cumulative distribution function of normal distribution and $Var_t R^p_{t+1}$ is the variance of the representative investor's portfolio.

International asset market structure

An international asset market consists of three assets: safe assets (for example, US T-bills), US risky assets (US stocks), and EME risky assets (emerging market bonds). The emerging bond market consists of bonds supplied by domestic banks in N individual EMEs. When low productivity is realized with a probability u, domestic banks default on these bonds. Therefore, the expected returns and the variance of the returns from investing one unit of tradable goods by diversifying across N symmetric countries follow Lemma 3.1.

[10]The bond price q_t should be lower than $\frac{1-u}{R}$ because international investors are concerned about the trade-off between the returns and risk of the portfolio and these bonds bear default risk. Otherwise, international investors never purchase these bonds in the presence of safe assets, which guarantee the gross risk-free rate of R. If international investors are risk neutral, then $q_t = \frac{1-u}{R}$. Therefore, $\frac{1-u}{R} - q_t$ denotes risk premium.

Lemma 3.1. (Returns distribution of emerging market bonds)

Returns on emerging market bonds follow a normal distribution with the following mean and variance:

$$E_t R^F_{t+1} \equiv \mu_{F,t+1} = 1 + i_t,$$

$$Var_t R^F_{t+1} \equiv \sigma^2_{F,t+1} = \frac{u(1+i_t)^2}{1-u},$$

where i_t also denotes the external cost of borrowing faced by borrowers in EMEs.[11]

Proof. For the proof, see Section A.2.1 in the online appendix. □

Under this representation of the expected returns on emerging market bonds, I attribute all the variations in the external cost of borrowing to the risk premium, as the physical probability of default is fixed in the model.

I also assume that the return process for US stocks is exogenous, and has a normal distribution with the following mean and variance:

$$E_t R^H_{t+1} \equiv \mu_{H,t+1}, \tag{10}$$

$$Var_t R^H_{t+1} \equiv \sigma^2_{H,t+1}.$$

The perceived returns on US stocks (H) and emerging market bonds (F) have conditional joint-normal distributions (with means $\mu_{j,t+1}$ and variances $\sigma^2_{j,t+1}$ for $j = H, F$) that are based on the period-t information set of the investors. The correlation of returns from two risky assets is $\rho > 0$.[12] Denoting the portfolio weight on each asset by $\omega_{S,t}$, $\omega_{H,t}$, and $\omega_{F,t}$, the expected returns and the variance of the representative investor's portfolio are:

$$E_t R^P_{t+1} = \omega_{S,t} R + \omega_{H,t} E_t R^H_{t+1} + \omega_{F,t} E_t R^F_{t+1} = \mu_{P,t+1}, \tag{11}$$

$$Var_t R^P_{t+1} = \omega^2_{H,t} Var_t R^H_{t+1} + \omega^2_{F,t} Var_t R^F_{t+1} + \omega_{H,t}\omega_{F,t} Cov_t(R^H_{t+1}, R^F_{t+1}) = \sigma^2_{P,t+1},$$

where $\omega_{S,t} + \omega_{H,t} + \omega_{F,t} = 1$ and R is the gross risk-free interest rate. Then (11) is used in the maximization problem of the representative investor (7).

[11] Note that i_t is a sufficient statistic for the expected returns and the variance of emerging market bonds due to the property of independently, identically distributed (i.i.d.) binomial distribution of aggregate productivity shocks.

[12] Positive correlations of asset returns are based on ample empirical evidence. If the correlations of asset returns are negative, then the VaR constraint is not necessary for the main result, and the simple mean-variance maximization will also deliver a reduced demand for emerging market bonds when the conditional variance of US stock returns increases.

3.3 Equilibrium of the model

For every period, investment and financing decisions are determined by the non-tradable sector managers' interactions with international investors via an emerging bond market.

Tradable sector firm's profit maximization

The profit maximization of unconstrained tradable sector firms, after the realization of the aggregate productivity shock, delivers the following demand function for non-tradable goods:

$$d_t(p_t) = \left(\frac{\alpha a_t}{p_t}\right)^{\frac{1}{1-\alpha}}. \tag{12}$$

Domestic bank's profit maximization

In this economy, borrowing constraints occur in equilibrium because a young manager can divert investable funds after production, provided she incurs a cost proportional to her funds $h(n_t + b_t)$, where h is a measure of the contract enforceability, in advance and the firm is solvent in the next period ($\pi_{t+1}(p_{t+1}) \geq 0$). To model credit market imperfections in EMEs, I assume $h < R$.[13]

Assumption 3.1. (Credit market imperfections)

In EMEs, a credit market is imperfect:

$$h < R.$$

As domestic banks take on currency mismatch, they should take account of the expected changes in the real exchange rate $\frac{1}{p_t}$ when they make a lending decision. The high-price state $\bar{p}_{t+1}$ will be realized with a probability of $1 - u$, and the low-price state $\underline{p}_{t+1}$ will be realized with a probability of u, as a result of the aggregate productivity realization. Therefore, from the profit maximization of domestic banks, domestic lending rates i_t^D must satisfy the following break-even condition:

$$E_t[p_{t+1}](1 + i_t^D) \equiv [(1-u)\bar{p}_{t+1} + u\underline{p}_{t+1}](1 + i_t^D) = 1 + i_t. \tag{13}$$

Therefore, domestic banks will finance the young manager only if the expected debt repayment does not exceed the diversion cost:

$$E_t[p_{t+1}](1 + i_t^D)b_t \leq h(n_t + b_t). \tag{14}$$

[13]This is because $R < 1 + i_t$, and $E_t[p_{t+1}](1 + i_t^D) = 1 + i_t$ in any equilibrium. If h is large enough that the condition $h \geq 1 + i_t$ is satisfied, then diversion becomes more expensive than the repayment, and the diversion costs have no effect on the lending decisions of domestic banks. I assume that this is the case for advanced economies, so borrowing constraints do not arise in advanced economies.

Interaction between a domestic economy and an international asset market

Demand for external credit by domestic banks and supply of external credit by international investors integrate a domestic economy with an international asset market. This is the main transmission channel of financial uncertainty shocks from the US economy to EMEs. I derive the demand and the supply function of the external credit in turn.

Non-tradable sector firm's maximization

As non-tradable sector managers cannot commit to repay their debt, no-diversion conditions (14) become borrowing constraints in equilibrium. If an investment yields an expected return that is higher than the opportunity cost of capital, the non-tradable sector firm will borrow up to an amount that makes the borrowing constraints (14) binding. Assumption 3.2 shows the condition for borrowing constraints to bind.

Assumption 3.2. In period t, the non-tradable sector productivity θ is sufficiently high:

$$\theta > \frac{p_t}{E_t p_{t+1}} h.$$

Given the external cost of borrowing i_t, binding borrowing constraints allow for the expression of the demand of external credit as a function of the time-t young manager's net worth.

Lemma 3.2. (Credit demand curve)

Demand of external credit from each economy increases with the young manager's net worth and decreases with the external cost of borrowing:

$$b_t = f(i_t, n_t; \theta_1) = (\mu(i_t) - 1)n_t, \tag{15}$$

where $\theta_1 = \{h\}$ *is a set of relevant parameters of the model, and* $\mu(i_t) = \frac{1}{1-h(1+i_t)^{-1}}$ *is a leverage of non-tradable sector firms.*

Proof. For the proof, see Section A.2.2 in the online appendix. □

Corollary 3.3. (Domestic investment)

Investment by the non-tradable sector becomes:

$$I_t = \frac{\mu(i_t)}{p_t} n_t \tag{16}$$

Proof. For the proof, see Section A.2.3 in the online appendix. □

International investor's profit maximization

When the representative investor determines her portfolio weights for each asset, she takes the expected returns from emerging market bonds $1 + i_t$ as given. Her decision on $\omega_{F,t}$, however, will affect i_t in equilibrium. The representative investor's demand for emerging market bonds is a function of the expected returns and the investor's wealth.[14]

Lemma 3.4. (Credit supply curve)

The representative investor's supply of credit b_t to each economy increases with the expected returns and her wealth:

$$b_t = g(i_t, W_t; \theta_2) = \frac{\omega_{F,t}(i_t; \theta_2) W_t}{N}, \tag{17}$$

where $\omega_{F,t}$ is a function of i_t and $\theta_2 = \{\mu_H, \sigma_H^2, \rho, R, \underline{R}, \gamma\}$.

Proof. For the proof, see Section A.2.4 in the online appendix. □

Market clearing

The emerging bond market clears by i_t that equates the demand for external credit (15) to the supply of external credit (17). Therefore, the emerging bond market clearing condition is

$$(\mu(i_t) - 1) n_t = \frac{\omega_{F,t}(i_t; \theta_2) W_t}{N}. \tag{18}$$

Finally, the non-tradable goods market clearing condition is

$$d_t(p_t) + I_t(p_t) = y_t^N(I_{t-1}), \tag{19}$$

where $d_t(p_t)$ is derived from (12) and $I_t(p_t)$ is derived from (16). Because y_t^N is predetermined by the investment in the previous period, the realization of productivity shocks in the current period determines the price of non-tradable goods.

The following concept of equilibrium integrates the representative investor's portfolio allocation decision with the rest of the economy.

Definition 3.1. ***An equilibrium*** *of the model is a collection of stochastic processes $\{\omega_{S,t}, \omega_{H,t}, \omega_{F,t}, b_t, I_t, d_t, n_t, W_t, y_t^T, y_t^N\}$ that solves the maximization problem for international investors, non-tradable sector firms, tradable sector firms, and domestic banks, and a collection of prices $\{p_t^T, p_t^N, q_t, i_t, i_t^D\}$ such that:*

(i) The emerging bond market clears by (18).

(ii) The non-tradable goods market clears by (19).

[14] Note that the representative investor's expected returns of investing in emerging market bonds equal to the external cost of borrowing by domestic banks.

(iii) Internal funds evolve according to (5) for $t \geq 1$, and n_1 equals $(1-\beta)p_0 y_0^N$ units of tradable goods. Young time-0 managers are endowed with n_0 units of tradable goods, and old time-0 managers are endowed with y_0^N units of non-tradable goods without debt.

Then, the following Proposition 3.5 fully characterizes the evolution of the key variables as a function of the state variable n_t.

Proposition 3.5. (Equilibrium path of the economy)

Given a non-tradable sector manager's net worth n_t, the equilibrium path of the key domestic variables is:

(i) Domestic credit b_t and the external cost of borrowing i_t are jointly determined by the emerging bond market equilibrium (18).

(ii) After the realization of a_t, investment I_t and the inverse of the real exchange rate p_t are jointly determined by (16).

(iii) The real exchange rate $\frac{1}{p_t}$, associated with the "good" ($\frac{1}{\bar{p}_t}$) and the "bad" states ($\frac{1}{\underline{p}_t}$), follows:

$$\left(\alpha a \frac{1}{\bar{p}_t}\right)^{\frac{1}{1-\alpha}} + \mu(i_t) n_t \frac{1}{\bar{p}_t} = y_t^N \quad \text{with a probability } \ 1-u \tag{20}$$

$$\frac{1}{\underline{p}_t} = \frac{y_t^N}{\mu(i_t) n_t} \qquad \text{with a probability } \ u.$$

(iv) n_t evolves according to:

$$n_{t+1} = (1-\beta)\Big(p_t y_t^N - p_t(1+i_{t-1}^D) b_{t-1}\Big) \text{ for } t \geq 1 \tag{21}$$

$$= (1-\beta) p_t y_t^N \qquad \text{for } t = 0$$

v) n_0 and y_0^N are given.

3.4 Discussion of the setup

In this section, I discuss how empirical regularities observed in EMEs are embedded in the structure of the model. As in the framework of Schneider and Tornell [2004], borrowing constraints in the non-tradable sector provide the key for propagating external shocks to EMEs.[15] As the production of non-tradable goods takes one period, non-tradable sector firms have to borrow to finance their investment, but they can only

[15] The distinction between tradable and non-tradable goods is also key to understand real exchange rate fluctuations (Rabanal and Tuesta [2013]).

borrow from domestic banks. This is because non-tradable sector firms do not have export receivables that can be used as collateral to foreign lenders. For further evidence of the asymmetry in financing opportunities in other EMEs, see Tornell and Westermann [2002].

Given the particular interest toward the short-run dynamics of US financial uncertainty shocks, ensuring a balanced growth path of the economy is not the main focus of this paper. As non-tradable sector managers accumulate net worth, the supply of emerging market bonds will dominate the demand from international investors in the limit, unless an infinite period maximization for international investors is considered. To obtain the closed-form solution for portfolio shares on emerging market bonds, I consider only the intertemporal decision in the period $t < T$. In this vein, the overlapping generation structure in the non-tradable sector has an advantage, in that financial decisions can be analyzed on a period-by-period basis. In particular, the equilibrium equations for investment and net worth do not include future prices.

The introduction of VaR constrained international investors has a similar implication on safe and risky asset prices as that discussed by Gourio [2012]. In Gourio [2012], risky asset prices fall because of an increased demand for precautionary savings, whereas in my analysis it is an outcome of the binding VaR constraint. Because international investors in the model specialize in the emerging bond market, I assume that the relative sizes of the US Treasury bond market and the US stock market are much larger than the wealth of the representative investor. Therefore, the decision of the representative investor cannot affect the prices in these two markets. Although more a realistic description of the US stock market is feasible, I assume the exogenous return process to obtain a closed-form solution.[16]

The VaR constraint is essential for the one-to-one mapping from VIX to the shock in the model ($\sigma^2_{H,t+1}$), but it can be replaced by a more general form of a standard mean-variance utility-maximization problem by shocking the degree of the investor's risk aversion. A shock to the risk aversion can be identified by VIX under the assumption that VIX captures the time-varying risk aversion of investors (Bekaert et al. [2013]; De Bock and de Carvalho Filho [2015]).The VaR constraint, however, provides a simple explanation for why US financial uncertainty shocks act as risk aversion shocks.[17]

During the flight to safety episodes, asset markets in EMEs tend to suffer indiscriminately to a large extent (Pavlova and Rigobon [2008]). This is because international investors view risk in these assets as largely homogenous rather than country-specific. To capture this empirical regularity, I consider a framework in which the presence of risk

[16]See Adrian and Shin [2014] for more realistic setups for studying the asset market implication and the microfoundations of the VaR constraint.

[17]As an alternative explanation, Gourio [2012] constructs a model in which VIX is driven by a disaster probability.

encourages international investors to reduce their portfolio share in the emerging bond market, regardless of the individual realization of the aggregate productivity shock.[18] The *i.i.d.* binomial distribution of the country-level aggregate productivity and the presence of a large number of countries imply that returns on the portfolio of emerging market bonds follow a normal distribution.

4 Structural VARs

I derive in two steps the structural VARs that link VIX to domestic variables. The first step involves deriving a structural link between VIX and the emerging bond market variables. Then, the emerging bond market variables are connected to the other domestic variables from Proposition 3.5.

Transmission mechanism of US financial uncertainty shocks

I consider the effect of US financial uncertainty shocks on $i_t^D - r_t$ and b_t. In the model, I define a shock to VIX as a one period increase in the conditional variance of US stock returns; $\sigma^2_{H,t+1}$. As the risk-free interest rate is constant in the model and the domestic lending rate i_t^D is proportional to the external cost of borrowing i_t, it is sufficient to specify the evolution of i_t as a function of $\sigma^2_{H,t+1}$.

Proposition 4.1. (Impact of US financial uncertainty shocks on the emerging bond market)

An increase in US financial uncertainty (i) decreases equilibrium domestic credit and (ii) increases the equilibrium external cost of borrowing.

$$\frac{\partial b_t}{\partial \sigma^2_{H,t+1}} < 0 \text{ and } \frac{\partial i_t}{\partial \sigma^2_{H,t+1}} > 0 \tag{22}$$

Proof. For the proof, see Section A.2.5 in the online appendix. □

Proposition 4.1 is derived from the emerging bond market clearing condition (18). It describes how US financial uncertainty shocks affect a credit market in EMEs, and can be tested empirically. A sudden increase in the conditional variance of US stock returns makes US stocks more risky holding the same expected returns, and thus creates an incentive to reallocate the portfolio toward other risky assets (a substitution effect). However, any given portfolio of risky assets becomes more risky, thus creating the incentive to reduce demand for all kinds of risky assets to respect the VaR constraint (an income effect). As described in Section A.2 in the online appendix, the income effect dominates the substitution effect when international investors are sufficiently leveraged

[18] The cross-country empirical analysis in Section 5.5 describes the role played by country-level credit market imperfections in explaining the impact of US financial uncertainty shocks on a domestic credit market.

as a result of the loose VaR constraint (corresponding to large γ). By way of the international investors' portfolio reallocation, US financial uncertainty shocks act as a risk-aversion shock that reduces credit supply to EMEs. By exploiting the role of a structural parameter h (the degree of contract enforceability) in amplifying the impact of US financial uncertainty shocks, another empirically testable prediction can be derived.

Corollary 4.2. (Impact of US financial uncertainty shocks and credit market imperfections)

US financial uncertainty shocks have a more adverse impact on the external cost of borrowing in a country with a lower degree of contract enforceability:

$$\frac{\partial^2 i_t}{\partial h \partial \sigma^2_{H,t+1}} < 0 \tag{23}$$

4.1 Average equilibrium path

By combining Proposition 4.1 with Proposition 3.5, the average equilibrium path that is needed to identify structural VARs becomes fully characterized. As the probability distribution of the aggregate productivity shock is *i.i.d.*, there is no need to keep track of history to compute the average equilibrium path. I use $\tilde{X}_t$ to denote the average value of X_t across two states (good and bad).

First, Proposition 4.1 has a clear implication on how US financial uncertainty shocks affect domestic credit b_t and the external cost of borrowing i_t. b_t and i_t are affected contemporaneously by $\sigma^2_{H,t+1}$ alone, through the reduction of the demand for emerging market bonds. Note that the portfolio allocation decision of international investors occurs before the realization of a_t, implying $i_t = \tilde{i}_t$ and $b_t = \tilde{b}_t$ for every t.[19]

Then, $\tilde{b}_t$ and $\tilde{i}_t$ recursively determines the inverse of the real exchange rate p_t. Once $\tilde{b}_t$ and $\tilde{i}_t$ are obtained, then the non-tradable good market clearing condition (19) pins down p_t. Depending on the realization of a_t, p_t takes a value of either $\bar{p}_t$ or $\underline{p}_t$, and the probability of each state is fixed. The average equilibrium price path is

$$\tilde{p}_t = (1-u)\bar{p}_t + u\underline{p}_t, \tag{24}$$

where $\bar{p}_t$ and $\underline{p}_t$ can be obtained from (20).

The last variable in the structural VARs is real GDP y_t, which is the value of domestic production of this economy in terms of tradable goods:

$$y_t = p_t I_t + y_t^T. \tag{25}$$

[19]For the same reason, n_t does not depend on the realization of a_t ($n_t = \tilde{n}_t$ for every t).

From the demand function of a tradable firm (12), it is clear that $d_t = \left(\frac{\alpha a}{\bar{p}_t}\right)^{\frac{1}{1-\alpha}}$ with a probability $1-u$ and $d_t = 0$ with a probability u. Therefore, the average equilibrium path of y_t is

$$\tilde{y}_t = \tilde{p}_t \tilde{I}_t + \tilde{q}_t^T = \mu(\tilde{i}_t)\tilde{n}_t + (1-u)a\left(\frac{\alpha a}{\bar{p}_t}\right)^{\frac{\alpha}{1-\alpha}}, \tag{26}$$

where $\tilde{y}_t$ is contemporaneously affected by the other three variables.

4.2 Identifying structural shocks

The above sequence of actions traces the effects of a shock to $\sigma^2_{H,t+1}$ on emerging market domestic variables. This recursive structure of the average equilibrium path implies the VARs with a lower triangular structure. To evaluate the role of country-specific factors in explaining the impact of US financial uncertainty shocks, I separately estimate the VARs with individual country data.[20] The following representation summarizes the structural VARs:

$$AY_{i,t} = \sum_{k=1}^{p} B_k Y_{i,t-k} + \epsilon_{i,t}, \tag{27}$$

$$Y_{i,t} = \begin{pmatrix} \Delta\sigma^2_{H,t+1} \\ \Delta\tilde{i}^D_{i,t} - r_t \\ \Delta\tilde{p}_{i,t} \\ \Delta\tilde{y}_{i,t} \end{pmatrix}, A = \begin{pmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 \\ a_{41} & a_{42} & a_{43} & 1 \end{pmatrix}, \text{ and } \epsilon_{i,t} = \begin{pmatrix} \epsilon^{\sigma^2_H}_{t+1} \\ \epsilon^{i^D - r}_{i,t} \\ \epsilon^{p}_{i,t} \\ \epsilon^{y}_{i,t} \end{pmatrix}, \tag{28}$$

where Y is a vector of economic variables, i denotes countries, t indicates a time period, and Δ denotes a change in the variable.

Intuitive description of the mechanism

The propagation mechanism of US financial uncertainty shocks in EMEs can be described intuitively using the structural VARs for guidance. First of all, given the current portfolio share and the perceived return process, international investors respond to a sudden increase in uncertainty by reducing their portfolio share on emerging market bonds, which act as sudden stops from the perspective of EMEs. This mechanism explains why VIX is highly correlated with global risky asset prices beyond any real linkages would suggest (Rey [2015]) and it is a robust predictor of capital flows to/from EMEs (Fratzscher [2012]). As US financial uncertainty shocks only shift a credit supply curve, and not a demand curve, country borrowing spreads increase in EMEs.

Given the current level of net worth, the increase in borrowing spreads results in less investment and a real depreciation by way of tighter borrowing constraints (16),

[20] As the number of variables (up to six) in the structural VARs is relatively smaller than the length of time-series data (over 200 periods), a panel VAR model is not considered to allow heterogenous dynamics of US financial uncertainty shocks.

which are often observed during sudden stop events. A real depreciation, independently from the realization of the aggregate productivity shock at a country level, explains the coincidence of spikes in VIX and synchronized depreciation of emerging market currencies. A real depreciation also reduces the next-period net worth of managers (balance-sheet effect) from (21). Finally, real output falls from (25), and less investment will lead, from (2), to a lower production of non-tradable goods in the next period.

Uncertainty will return to the pre-shock level after one period, so the VaR constraint no longer binds at the next period. Therefore, the external cost of borrowing falls and domestic credit increases at the given level of net worth, which reverses the vicious cycle described above. The overall contractionary effect, however, lasts more than one period because of the negative effects on the accumulation of net worth.

5 Estimating the model

5.1 Empirical implementation of structural VARs

This section provides an empirical implementation of the structural VARs identified by (27) and (28). I identify a shock to $\sigma^2_{H,t+1}$ from a one standard deviation increase in the period-t value of VIX. Because VIX is a forward-looking volatility of US stock returns and $\sigma^2_{H,t+1}$ is the conditional variance of US stock returns known in period t, VIX_t is a time-consistent measure of $\sigma^2_{H,t+1}$. I place US output $y_{US,t}$ before VIX_t in $Y_{i,t}$ to control for a real disturbance from the US economy. Despite the strong evidence in Figure 1, I cannot fully rule out the possibility that fluctuations in uncertainty are an endogenous response to business cycles (Bachmann et al. [2013]). This empirical implementation permits a conservative estimate to be made of the impact of US financial uncertainty shocks that are controlled by the US output shocks.

In the empirical implementation, $Y_{i,t}$ and $\epsilon_{i,t}$ in (28) are replaced by their counterparts in (29). I impose further identifying restrictions by preventing feedback from domestic variables into the US variables ($B_{k,1,j} = B_{k,2,j} = 0$ for all $j \neq 1,2$ and $k = 1,2,...,p$). This block exogeneity restriction is consistent with a small open-economy assumption in the model.[21]

$$Y_{i,t} = (\Delta y_{US,t}, \Delta VIX_t, \Delta \tilde{i}^D_{i,t} - r_t, \Delta \tilde{p}_{i,t}, \Delta \tilde{y}_{i,t})', \tag{29}$$

$$\epsilon_{i,t} = (\epsilon^{y_{US}}_t, \epsilon^{VIX}_t, \epsilon^{i^D - r}_{i,t}, \epsilon^{p}_{i,t}, \epsilon^{y}_{i,t})'.$$

Structural VAR model of the US economy

[21] Relaxing the small open-economy assumption and letting the data free to speak regarding this assumption do not change the main results.

To compare the impact of US financial uncertainty shocks on EMEs from the impact on the US economy, I implement a structural VAR model of the US economy parallel to that of EMEs. Under the international asset market segmentation, I include the risk-free rate in the structural VAR model of the US economy. Following the notion of US financial uncertainty shocks as a driver of the US business cycle in the prior literature (Bloom [2009]), I place VIX_t before Y_t, and do not impose a small open-economy assumption:

$$Y_t = (\Delta VIX_t, \Delta r_t, \Delta p_{US,t}, \Delta y_{US,t})', \tag{30}$$

$$\epsilon_t = (\epsilon_t^{VIX}, \epsilon_t^{r}, \epsilon_{US,t}^{p}, \epsilon_t^{y_{US}})'.$$

The empirical results from the US economy may contain the wealth effect (Kyle and Xiong [2001]) of US financial uncertainty shocks through a fall in W_t, as the high volatility of stock returns is more often accompanied by a crash in a stock market than a rally. Taking into account this additional effect, the estimates from the following VAR should be taken as an upper bound on the quantitative importance of US financial uncertainty shocks on the US economy.[22]

5.2 Data

This section describes macroeconomic data of the 18 EMEs and the US economy used in the estimation of structural VARs. Unlike previous studies on uncertainty shocks in the emerging market context (Matsumoto [2011]; Akıncı [2013]; Carrière-Swallow and Céspedes [2013]), I employ monthly macroeconomic data throughout the structural VARs, focusing on the short-run nature of US financial uncertainty shocks. The choices of sample countries and sample periods are mainly restricted by the availability of monthly data. Table 1 lists the 18 EMEs studied in the paper with their sample coverage. As my analysis is not restricted to a certain regional group of countries or crisis episodes, the following empirical results gain a general implication. Section A.1.1 in the online appendix provides a complete description of and sources of the data used in the analysis.

Most empirical studies on EMEs use quarterly variables due to the limited availability of data, but using monthly variables has four main advantages toward studying the impact of US financial uncertainty shocks in the context of structural VARs. First, it helps discover relevant short-run dynamics because jumps in VIX typically last only for a few months. Aggregation into the quarterly frequency would smooth out much of the variation. Second, using higher-frequency variables mitigates the identification

[22] Once the level of the US stock market is placed before VIX to control for the wealth effect, the impact on US output is no longer negative even in the short run. See Figure 6 in Choi [2013] for a similar finding.

Table 1: Countries in the sample and the data coverage

Countries	Coverage	Countries	Coverage
Argentina	1994M1-2013M12	Philippines	1994M1-2013M12
Brazil	1996M1-2013M12	Poland	1994M1-2013M12
Chile	1994M1-2013M12	Russia	1996M1-2013M12
Czech	1994M1-2013M12	Singapore	1997M1-2013M12
Hungary	1994M1-2013M12	South Africa	1994M1-2013M12
Indonesia	1994M1-2013M12	Taiwan	1994M1-2013M12
Israel	1994M1-2013M12	Thailand	1994M1-2013M12
Korea	1994M1-2013M12	Turkey	1995M1-2013M12
Malaysia	1994M1-2013M12	US	1994M1-2013M12
Mexico	1996M1-2013M12		

Notes: The choice of sample countries and sample periods is mainly restricted by the monthly data availability.

issue when zero contemporaneous restrictions are used for structural interpretation. Zero contemporaneous restrictions on financial variables in quarterly data are difficult to justify. Third, it allows the inclusion of more lags in the VAR system, which helps alleviate the serial correlation issue in the relatively short period of the sample. Finally, the quarterly GDP data may not correctly capture behaviors of a private sector unless government expenditure is acyclical.

To measure domestic production at the monthly frequency, I use industrial production index. By using real effective exchange rates to measure real exchange rates, an increase in the real effective exchange rates indicates a real appreciation. I measure country borrowing spreads by the difference between domestic real lending rates and the real risk-free rate.[23] Therefore, the baseline model contains five variables, ordered as follows: the log of the US industrial production, VIX, country borrowing spreads, the log of domestic real effective exchange rates, and the log of domestic industrial production. Figure 3 describes the evolution of VIX during the sample period.[24]

Following Bloom [2009], all the variables in the structural VARs are de-trended using

[23] Although spreads from J.P. Morgan's Emerging Markets Bond Index Plus (EMBI+), corresponding to $i_t - r_t$ in the model, are often used to measure country spreads in EMEs (for example, Neumeyer and Perri [2005]; Uribe and Yue [2006]; Akıncı [2013]), I do not use them for three reasons: (i) EMBI+ index is based only on the spreads of dollar denominated sovereign bonds, which cannot capture the currency mismatch behavior in the private sector highlighted in the model. (ii) the EMBI+ index does not cover as many countries as bank lending rates, and (iii) it has substantially different starting and ending dates across countries, preventing a meaningful cross-country comparison. For example, the EMBI+ index for South Africa has only been available since 2002, and the index for Korea was no longer available after 2006. Nevertheless, Akıncı [2013] finds, from structural VARs on 6 EMEs, a similar degree of increase (0.3%) in the EMBI+ spreads after a one standard deviation increase in VIX.

[24] Bloom [2009]—further extended by Choi [2013]—identifies 17 exogenous events that led a spike in VIX since 1962. Among seven exogenous events during the sample period in this analysis, only one event (Asian Financial Crisis) is directly driven by EMEs, suggesting the implausibility of the reverse causality (fluctuations in VIX are driven by EME business cycles.

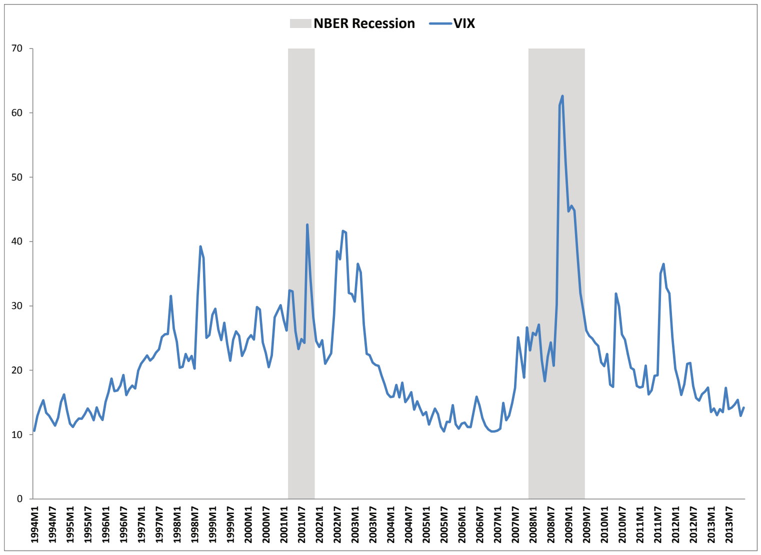

Figure 3: The evolution of VIX

Notes: This figure plots the evolution of VIX between January 1994 and December 2013.

a Hodrick-Prescott (HP) filter at the monthly frequency, so as to obtain a stationary series. I choose the appropriate lag-length of the six lags for all countries in the sample, as the Akaike information criterion typically suggests a lag-length between 3 and 6. Then, the model is estimated by maximum likelihood for each of the countries in the sample. Standard errors are estimated using a parametric bootstrapping procedure with 200 repetitions.

5.3 Main results

Figure 4 summarizes the main results from the structural VARs of EMEs and the US economy. The main results highlight the distinct impact of US financial uncertainty shocks on EMEs from the impact on the US economy. Because displaying impulse responses for every country would be too exhaustive, I first compare the results from Korea with those from the US, to demonstrate the different responses to US financial uncertainty shocks. Then, I run the VARs of the rest of the countries individually, to confirm whether EMEs share the results from Korea.

The response of key domestic variables in Korea is consistent with the prediction of the model. US financial uncertainty shocks are followed by an increase in country borrowing spreads and a real depreciation. A substantial fall in Korean output confirms the results from the bivariate VARs, as described in the Introduction. All of the responses of these variables are statistically and economically significant.

In the US, however, the response of key domestic variables is dramatically differ-

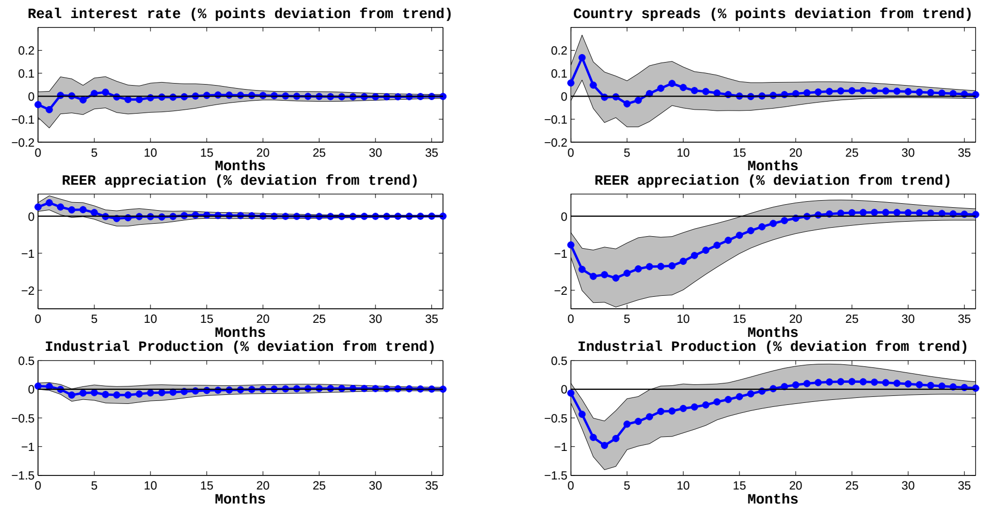

Figure 4: Responses to US financial uncertainty shocks: US versus Korea

Notes: This figure plots the response of real interest rates (country borrowing spreads for Korea), real effective exchange rates, and industrial production of the US (left) and Korea (right) to a one standard deviation increase in VIX.

ent. The risk-free interest rate decreases (although insignificantly) by 0.07%, and real exchange rates appreciate by 0.4%. A fall in the risk-free rate is key to distinguishing a US financial uncertainty shock from a typical liquidity shock, as a typical liquidity shock has a symmetric effect on both safe and risky assets (Matsumoto [2011]; Gourio [2012]). US financial uncertainty shocks have no impact on US output in either the large scale VARs or the bivariate VARs.[25]

Once the flight to safety mechanism is considered, the opposite behaviors of price variables between two economies are easy to understand: As long as US treasury bonds and US dollars serve as a reliable safe haven, the US economy will be the destination for the withdrawn funds from EMEs. Unless the supply of safe assets is perfectly elastic (although the model assumes so for simplicity), their price would increase. This result reinforces the importance of considering an international asset market to understand the transmission channel of US financial uncertainty shocks to EMEs.

Figure 5 further shows that a sharp increase in VIX during the 2008-09 global financial crisis was more relevant for EMEs than the US economy. Although the US subprime mortgage crisis has negatively affected US output since the beginning of 2008, VIX re-

[25] A recent study by Caldara et al. [2016] provide another explanation on the insignificant impact of uncertainty shocks on US output. They purge uncertainty shocks—also measured by VIX—from financial shocks—measured by the excess bond premium—and find that the effect of uncertainty shocks on US output is significant only if it is transmitted through a financial channel.

mained low until the bankruptcy of Lehman Brothers in October, 2008. Moreover, US financial uncertainty shocks only explain a small part of the decline in US output during the Great Recession, a finding in line with Choi and Loungani [2015] and Caldara et al. [2016]. In Korea, however, a larger fraction (1/4) of output decline is explained by US financial uncertainty shocks and a sharp fall in output follows the spike in VIX.[26] This is consistent with the observation that the US subprime mortgage crisis expanded to the global scale only after the collapse of US financial markets.

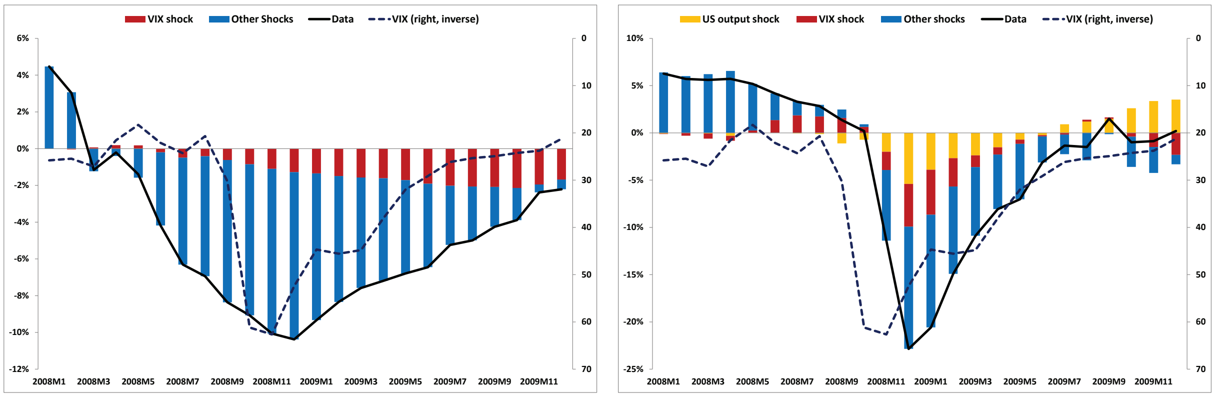

Figure 5: Historic decomposition of output during the Great Recession

Notes: This figure plots the contribution of US financial uncertainty shocks to changes in industrial production during the Great Recession for the US (left) and Korea (right). The solid lines indicate actual data; the blue bars indicate the simulated fluctuations in industrial production when all shocks except US financial uncertainty shocks (US output shocks and US financial uncertainty shocks for Korea) are turned on; and the red bars indicate the simulated fluctuations in industrial production conditional on the estimated US financial uncertainty shocks alone.

To represent the results from the 18 EMEs visually, Figure 6 shows the average and the median responses of the 18 EMEs with an interquartile range for the point estimates.[27] The results across countries differ to a large degree in terms of magnitudes, but the case of Korea is representative of the qualitative patterns. From the comparison of the responses between the US economy and the average pattern from the 18 EMEs, I find that the impact of US financial uncertainty shocks is qualitatively different between EMEs and the US economy.[28]

[26] This finding is consistent with Chudik and Fratzscher [2011], who state that EMEs have been more strongly affected by risk-appetite shocks—measured by VIX—than advanced economies during the global financial crisis.

[27] I do not plot confidence intervals for the average and the median response because US financial uncertainty shocks are not *i.i.d.* across countries. Common shocks to all the countries result in correlated error among countries, preventing a straightforward estimation of standard errors. See Carrière-Swallow and Céspedes [2013] for an alternative representation under similar circumstances.

[28] Arguably, the decline in EME output following US financial uncertainty shocks is rather large relative to their impact on financial market variables. This could be driven by omitted factors affecting both US financial uncertainty and EME output through other channels. Commodity prices are certainly such a factor, as a few countries in

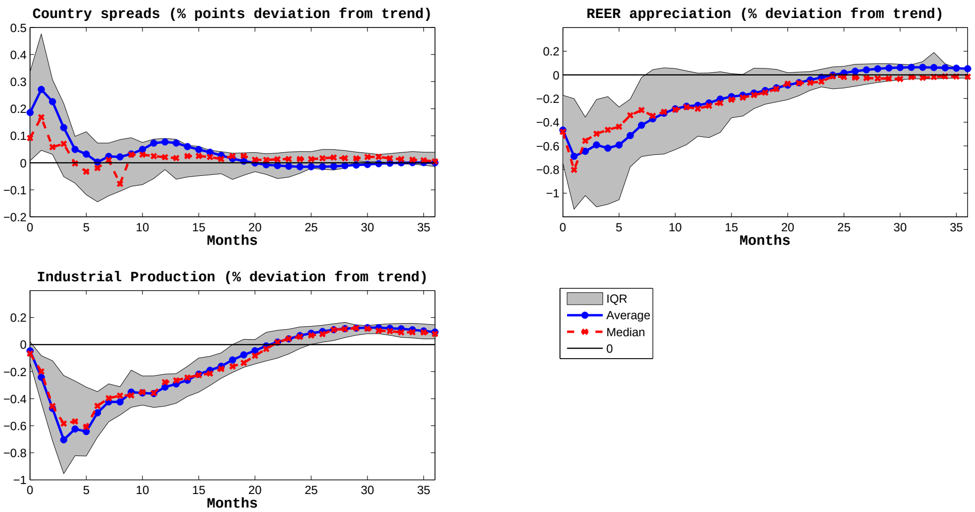

Figure 6: Responses to US financial uncertainty shocks: 18 EMEs

Notes: This figure plots the average (blue) and the median (red) responses of three macroeconomic variables (country borrowing spreads, real effective exchange rates, and industrial production) from the 18 EMEs in the sample and the corresponding interquartile range to a one standard deviation increase in VIX.

The next questions to ask are: (i) How important are US financial uncertainty shocks in explaining economic fluctuations in EMEs? and (ii) Which countries are particularly susceptible to US financial uncertainty shocks? Table 2 summarizes the variance decomposition of the domestic variables from the structural VARs at the 36-month horizon for each country in the sample. While US financial uncertainty shocks only explain insignificant and small (1%, 5%, and 2%) variances in the real interest rate, the real effective exchange rate, and industrial production of the US economy, much larger fractions of domestic variables in the 18 EMEs are explained by US financial uncertainty shocks, even after controlling for US output shocks. As the numerous shaded areas in the second to the fourth column of Table 2 indicate, the fraction explained by US financial uncertainty shocks is comparable to that of US output shocks.

5.4 Robustness checks

In this section, I explore whether the baseline results are robust to changes in the specification of the empirical model. First of all, HP-filtering of data is subject to

the sample are a commodity exporter and commodity prices are negatively correlated with VIX. To check this possibility, I re-estimate the baseline model by including the world commodity price and the US stock market index in the exogenous block. Section A.3.2 in the online appendix shows that this is indeed a case without affecting the conclusion of the paper. I appreciate an anonymous referee for pointing out potential omitted factors.

Table 2: Variance decomposition of the key variables

Response	VIX Country spreads	VIX REER	VIX Domestic output	US output Country spreads	US output REER	US output Domestic output
Argentina	17.10*	11.69	10.99	16.32	13.48	16.25
Brazil	8.30	27.91*	32.49*	11.67	3.82	18.01
Chile	9.33*	11.86*	9.13*	14.62	12.89*	16.22*
Czech	14.59	7.76	12.69	5.69	19.97	23.57*
Hungary	4.56	16.60	20.96	10.73	2.56	43.92*
Indonesia	4.62	9.19	6.20	11.37	6.59	5.11
Israel	1.55	2.41	12.56	4.56	16.42*	27.16*
Korea	4.25	36.81*	15.65	4.15	12.67*	10.80
Malaysia	4.77	7.45	19.74*	4.26	17.37	11.71
Mexico	10.48*	33.31*	22.98*	12.58	4.73	41.05*
Philippines	1.87	9.46	17.44*	2.43	9.37	15.10*
Poland	8.07	27.24*	7.18	5.88	4.78	17.55*
Russia	4.88	5.00	11.35	4.50	3.11	33.34*
Singapore	14.12*	2.82	6.88	4.98	18.28*	10.44
South Africa	4.86	9.76	27.86*	24.22*	5.83	16.36
Taiwan	10.10	25.52*	17.28*	2.97	8.03	47.95*
Thailand	14.44	6.03	25.87*	0.42	26.61*	9.90
Turkey	2.29	6.44	15.54*	13.13	4.65	30.62*
EME Average	7.68	14.29	16.27	8.58	10.62	21.95
	Real interest rates	REER	Domestic output			
US	0.69	5.30	1.98			

Notes: For EMEs, each statistic denotes the portion of the variance of forecasting error in each variable explained by a one standard deviation shock to VIX and US industrial production. For the US, each statistic denotes the portion by VIX only. I only report the variance decomposition at 36-month horizon to save space. All the numbers are in percentage and the shaded area indicates statistical significance at 10%.

a critique. Bachmann et al. [2013] criticize the VARs used in Bloom [2009] because filtering prior to estimation removes, by construction, persistent or permanent effects of US financial uncertainty shocks. To address this potential issue, I estimate the same structural VARs with levels of each variable. The exceptions are industrial production series, which are non-stationary for every country in the sample. For output series, I use linear de-trending to obtain stationary series.

Second, the choice of Cholesky ordering of the variables is critical in identifying orthogonal shocks. Although I derive a recursive structure from the equilibrium model, a potential mis-specification issue still remains. Therefore, I place the exogenous block $(\Delta y_{US,t}, \Delta VIX_t)'$ after the domestic block $(\Delta \tilde{i}_{i,t}^{D} - r_t, \Delta \tilde{p}_{i,t}, \Delta \tilde{y}_{i,t})'$ in $Y_{i,t}$ of (29).

Third, the sample period examined for this analysis only covers the last 20 years. This being the case, I should check the possibility that the main results are driven simply by the extreme event of the 2008-09 global financial crisis. Therefore, I re-estimate the

VARs using the period between 1994 and 2007.

Last, although I have applied the Akaike criterion to consistently select the appropriate lag lengths, some residual serial correlation may still be present. Taking into account the monthly nature of the data, I re-estimate the VARs with 12 lags.

Figure 7 shows the response of the key domestic variables under alternative specifications. To save space, I include the results from the US and Korea only. Section A.3.3 in the online appendix of this paper includes the individual impulse response functions of all 18 countries, along with the results from robustness checks. As the response of the key variables under different specifications resembles Figure 4, I conclude that the main results are not sensitive to these issues.

5.5 Credit channel

I have shown the strong negative impact of US financial uncertainty shocks on the 18 EMEs. Credit market imperfections, leading to binding borrowing constraints in EMEs, are key factor affecting the function of the credit channel. This section further investigates the credit channel as a propagation mechanism of US financial uncertainty shocks to EMEs.

In the model, contract enforceability h is an important structural parameter that distinguishes EMEs from the US economy and also governs the degree of credit market imperfections among EMEs. As shown in Corollary 4.2, the negative relationship between the degree of contract enforceability and the magnitude of the impact of US financial uncertainty shocks on the external cost of borrowing is expected. To gauge the magnitude of the impact, I use the maximum increase in country borrowing spreads within the 36-month horizon.

I measure country-level contract enforceability by employing four different indexes. There are two direct measures of h: (i) the strength of legal rights index from the World Bank Indicator, and (ii) the efficiency of debt enforcement index from Djankov et al. [2008]. In both indexes, a higher score indicates higher h. There are two indirect measures of h, taking into account the consequence of low contract enforceability in EMEs: (i) the financial depth index as measured by the domestic credit provided by financial sector as a percentage of GDP, from the World Bank Indicator, and (ii) the financial dollarization index, from the 2010 updated database by Yeyati [2006]. Section A.1.2 in the online appendix summarizes the construction of these indexes. Figure 8 shows a negative relationship between the measures of credit market imperfections and the magnitude of impact on the external cost of borrowing.

Because domestic credit and the external cost of borrowing are jointly determined in the model, I only employ the external cost of borrowing in the baseline VAR model.

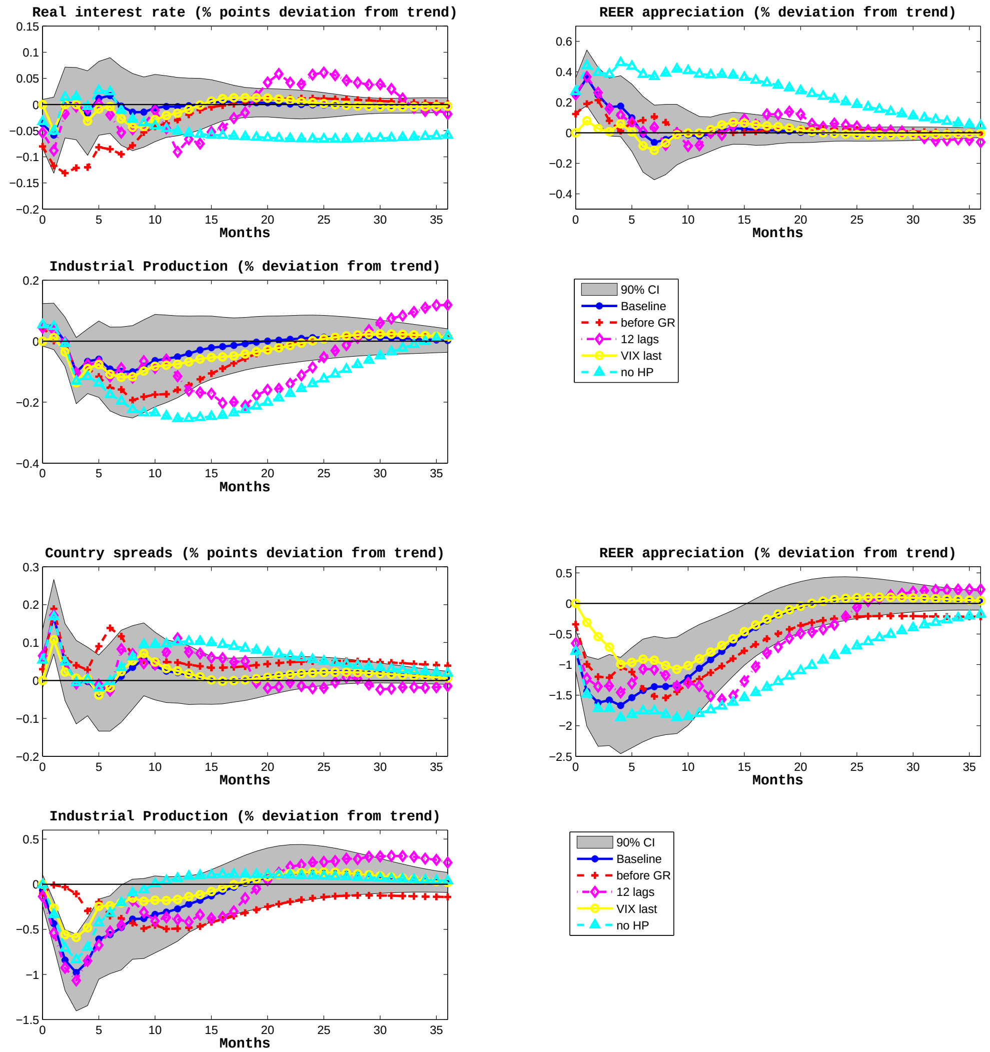

Figure 7: Robustness checks

Note: This figure plots the results from robustness checks for the US (top) and Korea (bottom). Shaded area indicates 90% confidence interval for the baseline specification. "before GR" denotes the baseline VAR with data from 1994 and 2007, "12 lags" denotes the baseline VAR but using 12 lags instead of 6 lags, "VIX last" denotes the VAR with the exogenous block placed after the domestic block to obtain conservative estimates of US financial uncertainty shocks, and "no HP" denotes the VAR without using HP-filter.

If US financial uncertainty shocks act as a negative credit demand shock, however, domestic credit and the external cost of borrowing would move in the same direction. To identify the credit channel, I add a variable for measuring the deviation of domestic credit from the trend Δb_t toward the domestic block of (29). To measure b_t, I use domestic credit provided to the private sector by deposit-money banks, from the Inter-

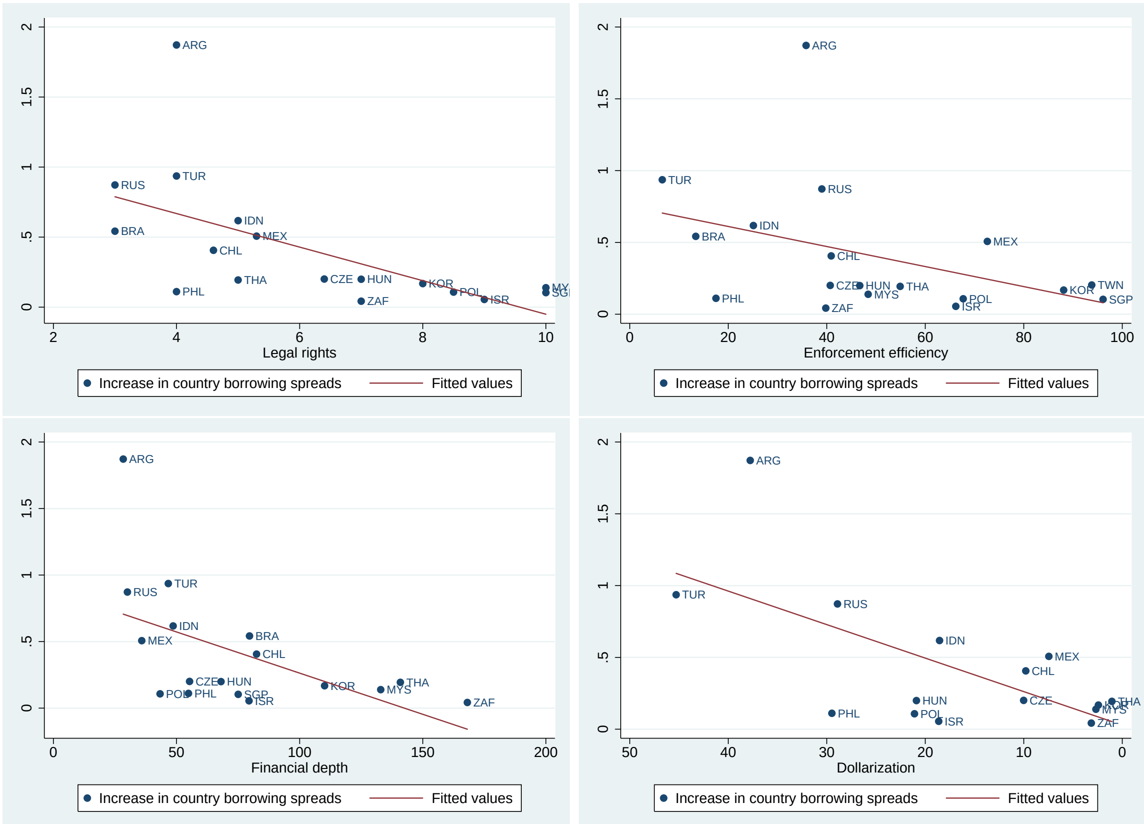

Figure 8: Degree of credit market imperfections and the adverse impact on a credit market

Notes: This figure shows a correlation between the degree of credit market imperfections, measured by four different indexes, and changes in country borrowing spreads in EMEs.

national Monetary Fund (IMF) International Financial Statistics (IFS), line 22D. Due to the limited availability of consistent data at the monthly frequency, I only include 11 countries for this extension: Argentina, Chile, Indonesia, Korea, Malaysia, Mexico, the Philippines, Russia, Taiwan, Thailand, and Turkey.

Figure 9 shows the average and the median responses of four domestic variables to a one standard deviation increase in VIX. These results further confirm the prediction of the model.[29] While country borrowing spreads immediately spike after the shock, domestic credit declines rather gradually from the trend, implying that an adjustment in the price occurs faster than that the adjustment in the quantity. The responses of country borrowing spreads and domestic credit indicate that US financial uncertainty shocks are a negative credit supply shock to EMEs.

Finally, I gauge the importance of the credit channel in explaining output drops during the 2008-09 global financial crisis by conducting a counterfactual exercise. For

[29] Individual IRFs are available in the online appendix Section A.3.4

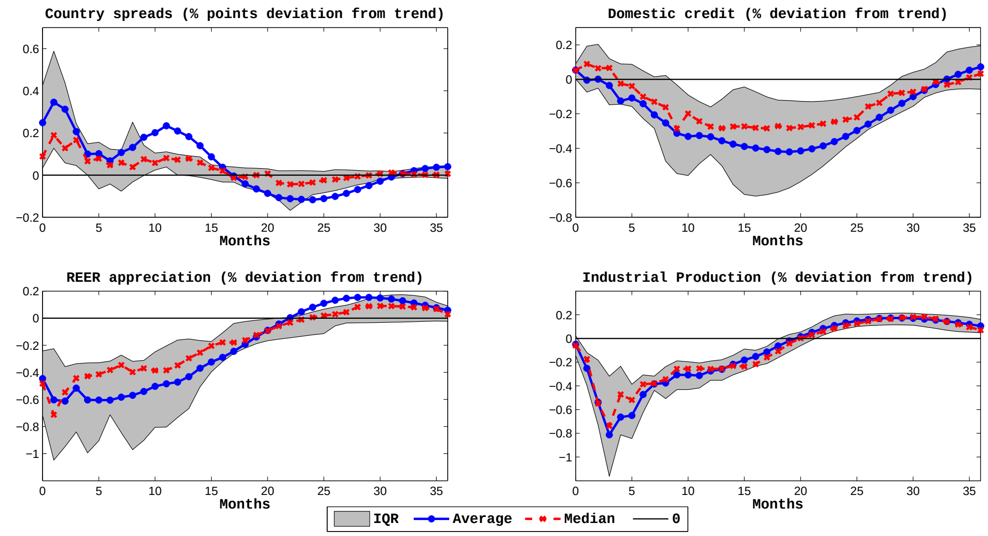

Figure 9: Response of the 11 EMEs to US financial uncertainty shocks in the extended VARs

Notes: This figure plots the average (blue), the median (red), and the interquartile range (shaded area) of the response of four domestic variables (country borrowing spreads, domestic credit, real effective exchange rates, and industrial production) in the 11 selected EMEs to a one standard deviation increase in VIX.

the 11 countries with the full data availability, I compare counterfactual changes in output when the credit channel is shut down to the actual changes in the data. I conduct this counterfactual exercise by assuming that country borrowing spreads and domestic credit are constant at the pre-crisis level. The average of the simulation results for the 11 countries in (shown in Figure 10) indicates that about a quarter of the average 8% decline of output from its trend in the 11 countries is explained by the credit channel. Section A.4 in the online appendix summarizes individual results from the 11 countries.

I also simulate numerically the part of the model that describes the international asset market, so as to gauge the quantitative effect of US financial uncertainty shocks on domestic lending rates in EMEs via the above portfolio reallocation of international investors. When key parameters of the model are calibrated, the model replicates the empirical estimates from the structural VARs under the admissible range of free parameters. See section A.5 in the online appendix for further details.

6 Conclusion

Contributing to the growing literature on uncertainty shocks as a new driver of business cycle fluctuations, I have presented an internally consistent model that explains the negative impact of US financial uncertainty shocks on EMEs. In my model, an

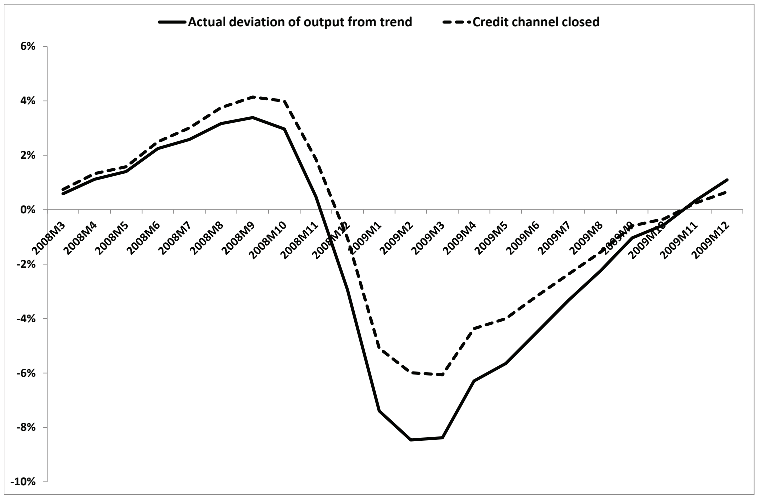

Figure 10: Importance of the credit channel during the Great Recession

Notes: This figure plots the average of actual deviation in output (solid) and counterfactual deviation in output by shutting down the credit channel (dashed) from its trend during the global financial crisis period from the 11 countries.

increase in US financial uncertainty is translated into an increase in risk aversion of international investors when they are subject to the VaR constraint. With the presence of credit market imperfections in EMEs, a risk-aversion shock acts as a negative credit supply shock. Structural VARs derived from the model allow me to identify shocks to US financial uncertainty and trace their spillover to borrowing spreads, credit, real exchange rates, and output of EMEs. Unlike other external shocks extensively studied in the previous literature such as commodity price shocks and US monetary policy shocks, the impact of US financial uncertainty shocks on EMEs, as contrasted to their impact on the US economy itself, emphasizes financial frictions as a propagation mechanism.

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