Pricing Risk Globally: Intermediary Constraints, the Dollar, and the Global Financial Cycle*

Özge Akinci†
Federal Reserve Bank of New York, CEPR

Şebnem Kalemli-Özcan‡
Brown University, NBER, CEPR

Albert Queralto§
Federal Reserve Board

July 2026

Abstract

We study how increased uncertainty about U.S. asset returns affects global asset prices and exchange rates in a two-country model with intermediary balance-sheet constraints. Empirically, uncertainty shocks widen global credit spreads, appreciate the dollar, and increase currency risk premia. In our model, higher uncertainty tightens intermediary constraints and lowers asset prices, reversing the counterfactual asset price increase in frictionless models. Because constraints make net worth especially valuable in bad times, risk premia respond strongly to uncertainty shocks. This interaction allows the model to match the credit spread, currency premium, and dollar responses in the data.

Keywords: Financial Frictions; Time-varying uncertainty, Intermediary Asset Pricing.

JEL classification: E32; E44; F41.

*An earlier version of the paper was previously circulated under the title "Uncertainty Shocks, Capital Flows, and International Risk Spillovers." The authors thank Mark Aguiar, Gianluca Benigno, Luigi Bocola, Pat Kehoe, Rohan Kekre, Linda Tesar, and Pablo Ottonello. Thanks to William Cross-Bermingham, Colleen Lipa, Serra Pelin, and Greg Simitian for excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York, the Board of Governors of the Federal Reserve, or the Federal Reserve System.

†Email: ozge.akinci@ny.frb.org.

‡Email: sebnem.kalemli-ozcan@brown.edu.

§Email: albert.queralto@frb.gov.

1 Introduction

A large literature documents a "global financial cycle" in risky asset prices closely tied to market perceptions of future risk, as proxied by indicators such as the VIX.[1] During "risk-off" episodes, risky asset prices decline around the world, the dollar appreciates, and many countries—particularly emerging markets—experience higher currency risk premia and destabilizing capital outflows; these patterns occur in reverse in"risk-on" episodes.[2] The leading interpretation attributes these dynamics to U.S. financial intermediaries that lend globally and contract credit supply when perceived risk rises.[3] This account, however, remains largely a narrative. It is not known whether a *single*, identified increase in risk—a pure second-moment shock—can quantitatively generate this constellation of comovements, nor what model ingredients are required to do so. As we show, this is not a trivial question: the natural frictionless benchmark predicts several of these comovements with the *wrong sign*.

We build a two-region general-equilibrium model of the global economy in which U.S.-based financial intermediaries intermediate credit globally subject to balance-sheet constraints, hold both risky and safe assets, and face time-varying uncertainty about the return to U.S. capital. We confront the model with empirically identified uncertainty shocks. Our central finding is that an uncertainty shock in the model reproduces, jointly and with the correct sign and magnitude, the main features of the data: large increases in corporate credit spreads in the U.S. *and* abroad, a persistent decline in the U.S. safe rate, an appreciation of the dollar, and a widening of the "uncovered interest parity" (currency risk) premium on foreign currencies. Balance-sheet constraints are the essential ingredient: without them, the same increase in uncertainty produces effects that differ from the data both qualitatively (wrong sign) and quantitatively (too small).

Figure 1 summarizes the facts that motivate our analysis. The first panel shows that the VIX (an index of expected U.S. stock market volatility) is strongly correlated with corporate credit spreads both in the U.S. and abroad. The second panel shows that this correlation extends to currency markets: the U.S. dollar tends to appreciate when the VIX rises. Consistent with the dollar evidence, the third panel shows that the VIX co-moves strongly with the expected excess returns on foreign currencies relative to the dollar (henceforth the UIP premium).

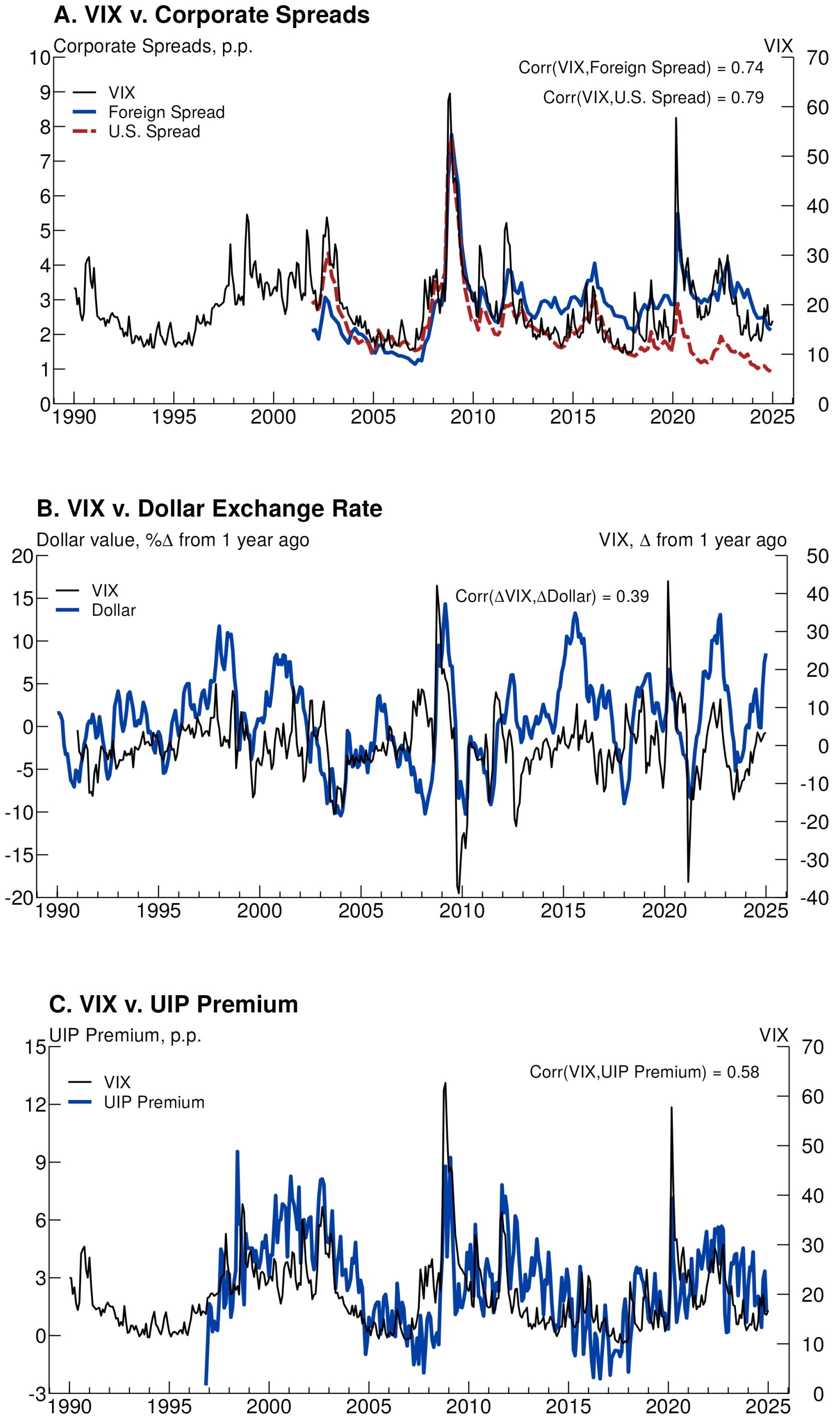
Our first step, in Section 2, is to formalize the suggestive evidence in Figure 1 and establish a precise set of magnitudes that the model aims to match. Following a methodology similar to Basu and Bundick (2017), we extract an exogenous component of the VIX and use a local-projections framework to identify the effects of an exogenous increase in the VIX. A one-standard-deviation shock (raising the VIX by about 15 points) is associated with an increase in credit spreads of between 0.2 and 0.3 percentage point, roughly a 0.5 percent appreciation of the dollar, an increase (decrease) in the UIP premium of foreign currencies (the dollar) of about half a percentage point, and a persistent decline in the U.S. long-term risk-free rate. These estimates are the quantitative

[1] See Miranda-Agrippino and Rey (2020).

[2] See Kalemli-Ozcan (2019) and di Giovanni et al. (2021).

[3] For example, Adrian and Shin (2014).

Figure 1: The VIX v. Corporate Spreads, the Dollar, and the UIP Premium



Note: The black line in all three panels shows the VIX, in levels (panels A and C) and in first differences (panel B). The blue and red dashed lines in panel A show foreign and U.S. corporate borrowing spreads, respectively. The foreign spread is an average of spreads across foreign economies. The blue line in panel B shows the percent change from a year ago in the value of the U.S. real dollar against a basket of foreign currencies. The blue line in panel C shows the "uncovered interest parity" premium, or expected excess currency returns, on foreign currencies. Foreign economies including both advanced economies and emerging markets with floating exchange rates (see Section 2 for details).

targets against which we evaluate the model.

Our contribution is to isolate a *single* mechanism that delivers these facts jointly—and to show that it is the same mechanism that overturns the standard frictionless benchmark. We feed a second-moment shock into an otherwise conventional model—Lucas-tree endowments, Gertler–Kiyotaki intermediary constraints, and standard preferences—and ask whether it can reproduce the global financial cycle quantitatively. It can: U.S. and foreign credit spreads rise nearly one-for-one, the dollar appreciates, the currency risk premium widens, and the U.S. safe rate falls, each close to its empirically estimated magnitude. The intuition behind the results lies in *why* the benchmark fails. Under frictionless asset pricing with conventional risk aversion, higher uncertainty *raises* the price of capital and *depreciates* the dollar—the opposite of the data—because precautionary saving lowers the safe rate by more than a negligible risk-premium response, lowering the required return. Intermediary balance-sheet constraints reverse both signs: the countercyclical marginal value of net worth makes the price of risk an order of magnitude more responsive to uncertainty, so risk premia rise enough to push asset prices down with higher required return (in spite of the fall in safe rate) and the dollar up. In this way, the constraint acts as a qualitative pivot on which the results turn.

Three literatures bear on our question, and our contribution is defined by what each leaves open. Work on the global financial cycle establishes the comovements but is largely descriptive or driven by first-moment shocks; it does not isolate the response to an identified change in risk. The closed-economy literature on uncertainty shocks shows that second-moment shocks contract activity and asset prices, but abstracts from global intermediation and from exchange rates. The literature on intermediary balance sheets shows that constraints amplify shocks, but typically does so for first-moment disturbances and in closed economies. We bring these together and show that the interaction of a second-moment shock with intermediary balance-sheet constraints—operating through the countercyclical marginal value of intermediary net worth—is what generates endogenous risk premia large enough to match the data jointly across asset classes, currencies, and safe rates.

In Section 3, we develop the two-region model. We consider an endowment economy with fixed stocks of risky physical capital in both countries and a government bond issued in the foreign currency. Owing to superior financial technology, U.S.-based intermediaries can intermediate assets globally, whereas foreign intermediaries cannot operate internationally. These global intermediaries face incentive constraints that limit their ability to expand balance sheets, as in Gertler and Kiyotaki (2010). Households in both countries (representing the broader nonfinancial sector) can also hold assets but face management costs of doing so, so global intermediaries are the marginal investors in asset markets. The return to U.S. capital is subject to time-varying uncertainty. A calibrated version of the model with an identified uncertainty shock reproduces the empirical magnitudes described above.

To isolate the economic mechanisms, in Section 4 we examine the role of key model features one at a time. We begin with an autarkic economy, which isolates the role of financial-intermediation frictions in transmitting uncertainty shocks and clarifies how intermediaries shape the pricing of risk. The logic is as follows. Removing the intermediation friction yields a standard asset-pricing economy *à la* Lucas (1978), in which, at conventional risk aversion, the effect of higher risk on the risk premium is very small and the price of capital *rises*, because higher precautionary saving lowers the risk-free rate.

With intermediation frictions, the price of capital *falls* even if the safe rate falls. The key channel is that intermediaries price assets using not only the marginal utility of future consumption but also the marginal value of a unit of net worth, which is highly countercyclical: in bad times constraints bind tightly and net worth is especially valuable. Through this channel the model implies a rise in the risk premium following an uncertainty shock that is an order of magnitude larger than in the frictionless economy, generating the large increase in credit spreads observed in the data. Moreover, the price of capital is no longer governed by the households' Euler equation but by the intermediaries' leverage constraint. An increase in risk about future returns lowers intermediaries' franchise value, worsens the incentive problem, and endogenously tightens the balance-sheet constraint, contracting the supply of credit available for financing capital and thereby lowering the price of capital.

The cross-border transmission of higher risk is governed by global intermediaries arbitraging risky assets across borders. The resulting no-arbitrage condition tightly links the price of capital in the U.S. and abroad, even though the underlying dividend processes are uncorrelated. An increase in the riskiness of U.S. assets therefore endogenously raises the risk premium on foreign capital, because the same constrained intermediaries are the marginal price-setters for both. This explains why the model generates an almost one-for-one increase in foreign credit spreads alongside U.S. spreads.

Finally, we turn to currency premia and the dollar. Global intermediaries are unconstrained in foreign safe bonds, so no-arbitrage via a version of uncovered interest parity holds—but with the relevant stochastic discount factor that of global intermediaries rather than households. Hence deviations from international arbitrage (currency risk premia) become influenced by the value of intermediary net worth. States in which the U.S. endowment is low—and the U.S. real exchange rate appreciates—are precisely states in which intermediary net worth is most valuable. Consequently the currency risk premium is far larger than without balance-sheet frictions and responds far more strongly to an increase in uncertainty, allowing the model to generate both a dollar appreciation and a sharp rise in foreign currencies' risk premia; a canonical two-country, two-good model without intermediation frictions instead implies a dollar depreciation and a much more modest UIP response. At the same time, constrained intermediaries shrink their balance sheets, shedding both risky assets and safe foreign bonds. This deleveraging pushes capital out of the foreign economy exactly when intermediary net worth is scarcest and most valuable, consistent with the global financial cycle documented by Miranda-Agrippino and Rey (2020), in which exogenous increases in risk drive synchronized capital flows and risk premia globally.

Literature. Our paper connects several literatures. The first studies the macroeconomic effects of uncertainty shocks, with well-known examples including Bloom (2009) and Basu and

Bundick (2017). This work is largely closed-economy and, for the most part, abstracts from financial frictions. A subset introduces financing frictions into closed-economy models with time-varying uncertainty—for example, Arellano et al. (2019) and Fernández-Villaverde and Guerrón-Quintana (2020)—while Alfaro et al. (2018) and Alessandri and Mumtaz (2019) provide direct evidence that financial frictions amplify uncertainty shocks, again mainly in closed economies. We depart from this literature in two ways that are essential to our results: the shock propagates through globally active intermediaries, and our object of interest is the joint response of global risky asset prices, currency risk premia, and the exchange rate—rather than the closed-economy quantity dynamics this literature emphasizes.

Because global intermediaries in our model price claims on risky capital both at home and abroad, as well as safe foreign government bonds denominated in foreign currency, the paper relates to the literature on intermediary asset pricing (e.g., He and Krishnamurthy, 2013 and Morelli et al., 2022), which ties asset prices and risk premia to frictions in financial intermediation. We differ in two respects. First, our intermediaries hold a multi-asset global portfolio—domestic and foreign corporate claims together with safe foreign-currency bonds—rather than a single risky asset. Second, the driving force is time-varying uncertainty rather than first-moment shocks to productivity or capital quality. The same two features separate us from the literature on international financial frictions (Gabaix and Maggiori, 2015; Itskhoki and Mukhin, 2021), in which shocks to currency intermediation generate volatile exchange rates and predictable deviations from UIP. There, the exchange-rate block is driven by a currency-specific friction, breaking international arbitrage; here, a single uncertainty shock about future risky asset dividends endogenously moves risky asset prices, UIP premia, and the value of the dollar together through one balance-sheet mechanism—precisely the comovement we document in the data.

A related strand links the exchange-rate value of the dollar to the "convenience yield" on dollar-denominated assets—the notion that these assets provide special liquidity and safety services to investors (Kekre and Lenel, 2024 and Jiang et al., 2021; see also Krishnamurthy and Vissing-Jorgensen, 2012). We share the prediction that the dollar appreciates when uncertainty rises, but obtain it without assuming any specialness of dollar-denominated assets: in our framework the dollar strengthens because the risk premium on foreign currencies rises endogenously through the interaction between balance-sheet frictions and aggregate uncertainty. We do not argue against the relevance of the dollar's specialness; rather, we offer a complementary mechanism that helps account for the observed effects of uncertainty shocks in the data.

Finally, the paper builds on the macro-finance literature on frictions in financial intermediation, most directly the framework of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011); see also Gertler et al. (2012), which emphasizes how risk perceptions shape intermediaries' balance sheets, and Akinci and Queralto (2023), which extends the framework to an open economy with cross-border spillovers. Our contribution within this class of models is to study time-varying uncertainty with globally active intermediaries that price assets across countries, and to show that this is what jointly generates the credit spread, currency premium, and exchange rate responses observed in the data.

The remainder of the paper develops the empirical analysis, presents the model and quantitative results, and concludes in Section 5.

2 Empirical evidence

This section provides empirical evidence on how U.S. uncertainty shocks affect global financial markets. We focus on three key outcomes: (i) expected excess returns on risky assets around the world, (ii) the value of the U.S. dollar vis-à-vis foreign currencies, and (iii) U.S. risk-free real interest rates.

To capture the global effects of uncertainty on risk premia, we examine two distinct types of excess returns. First, we use credit spreads on U.S. dollar-denominated corporate bonds issued by both U.S. and foreign corporations. These spreads–defined as the difference between corporate bond yields and comparable-maturity U.S. Treasury yields–measure the risk premium on corporate credit risk. Second, we measure deviations from uncovered interest parity (UIP), which capture the risk premium on currency (expected excess returns) when investors hold foreign currency government bonds relative to U.S. Treasuries. Together, these two measures allow us to assess how uncertainty shocks affect both credit risk premia and currency risk premia in global financial markets. Both measures are natural empirical counterparts to concepts in our theoretical model presented in Section 3, allowing for direct comparison between data and theory.

We proceed in two steps. First, we describe our identification strategy for isolating exogenous movements in U.S. uncertainty from endogenous responses to macroeconomic conditions. Second, we present estimates of the dynamic effects of identified uncertainty shocks on the financial variables described above.

2.1 Identification of uncertainty shocks

We identify uncertainty shocks using monthly data from 1990 to 2024. Our measure of uncertainty is the VIX index, which captures the expected volatility of U.S. stock returns over the next 30 days. To isolate exogenous movements in uncertainty from endogenous responses to macroeconomic conditions, we follow Basu and Bundick (2017) and estimate the following regression:

$$\text{VIX}_t = \alpha + \sum_{i=0}^{i=12} \beta_i X_{t-i} + \sum_{i=1}^{i=12} \gamma_i \text{VIX}_{t-i} + \epsilon_t \tag{1}$$

where X_t includes the 12-month percent change in U.S. industrial production and the level of the federal funds rate. These controls capture contemporaneous real activity and monetary policy conditions that may drive movements in the VIX. We use 12 lags to account for persistence in the variables. The residuals, ϵ_t, represent our identified uncertainty shocks—unexpected changes in uncertainty that are orthogonal to current fundamentals. This identification strategy aligns with our theoretical model, which features exogenous shocks to the volatility of expected future dividends on capital.

The identified uncertainty shocks over our sample period reveal that the largest shocks occur during well-known crisis episodes: the global financial crisis of 2008-2009 and the COVID-19 pandemic in 2020. Other notable spikes include the LTCM crisis in 1998, the burst of the dot-com bubble in 2000-2001, and the European sovereign debt crisis in 2011-2012. These episodes confirm that our identification procedure captures economically meaningful uncertainty events.[4]

2.2 Global effects of uncertainty shocks

We next estimate the dynamic effects of uncertainty shocks on key U.S. and foreign financial variables. We focus on five sets of financial variables that are central to understanding the international transmission of uncertainty: (i) U.S. and foreign corporate credit spreads, which measure expected excess returns on risky assets; (ii) UIP risk premia for holding foreign currencies, which measure deviations from international arbitrage conditions; (iii) the real value of the U.S. dollar vis-à-vis foreign currencies, as measured by the real broad dollar index; (iv) the U.S. risk-free real interest rate; and (v) the VIX itself.

These variables are not only commonly used in the literature documenting global financial cycle facts (Rey (2013), Kalemli-Ozcan (2019), and Miranda-Agrippino and Rey (2021)), but are also variables we can directly measure in the theoretical model presented in the next section. Moreover, as we show, examining the joint behavior of credit spreads on risky asset, safe rates, exchange rates, and UIP premia is critical for distinguishing second-moment uncertainty shocks from first-moment shocks to productivity or global bank's net worth.

With the identified uncertainty shocks in hand, we estimate impulse response functions using the local projection method of Jordà (2005). This approach allows us to trace out the dynamic effects of uncertainty shocks at different horizons without imposing many structural restrictions. We estimate the following specification separately for each horizon h:

$$y_{t+h} = \alpha_h + \beta_h \epsilon_t + \sum_{i=1}^{i=2} \eta_{h,i} \epsilon_{t-i} + \sum_{i=1}^{i=2} \gamma_{h,i} y_{t-i} + \upsilon_{t+h} \tag{2}$$

where y_{t+h} is the outcome variable of interest in month $t+h$ (measured h months after the shock), ϵ_t is the identified uncertainty shock, and we include two lags of both the dependent variable and the shock to control for persistence. The coefficient β_h traces out the impulse response function, showing the effect of a one standard deviation uncertainty shock on the outcome variable h periods ahead. We compute standard errors that are robust to heteroskedasticity and autocorrelation (HAC) using the Newey-West procedure.

For foreign credit spreads and UIP risk premia, we exploit the panel dimension of our data, which includes 17 countries (consisting of both advanced economies and emerging markets) over

[4] Figure B.11 in the Appendix shows the evolution of the raw VIX over the same period for comparison, and Figure B.12 plots the identified uncertainty shocks over our sample period.

our sample period.[5]

We estimate a panel version of the local projection:

$$y_{c,t+h} = \alpha_{c,h} + \beta_h \epsilon_t + \sum_{i=1}^{i=2} \eta^i_{h,c} \epsilon_{c,t-i} + \sum_{i=1}^{i=2} \gamma^i_{h,c} y_{c,t-i} + \upsilon_{c,t+h} \tag{3}$$

where $y_{c,t+h}$ refers to the outcome variable for country c in month $t+h$, and $\alpha_{c,h}$ is a country-specific fixed effect that absorbs time-invariant differences across countries. Crucially, all countries are regressed on the same U.S. uncertainty shock ϵ_t, so the coefficient β_h measures the average response of foreign variables to U.S. uncertainty. This specification allows us to test whether U.S. uncertainty shocks have spillover effects to foreign economies.

Figure 2 presents the estimated impulse responses of key financial variables to a one standard deviation U.S. uncertainty shock. The figure reveals several striking patterns.

The VIX increases by 15 percent on impact and remains elevated for about 6-8 months before gradually returning to its pre-shock level, confirming that the shock generates persistent increases in expected volatility.

Both U.S. and foreign credit spreads rise sharply, peaking at approximately 0.3 percentage points one month after the shock. The near-identical responses suggest strong international co-movement in risk premia. The effects dissipate after about 8-10 months, with foreign spreads exhibiting slightly more persistence.

The broad dollar appreciates by approximately 0.5 percent on impact, though this effect is not highly persistent. In contrast, the UIP risk premium for holding foreign currencies rises by approximately 0.5 percentage points and remains significantly elevated for nearly two years. This large and persistent increase indicates that uncertainty shocks generate substantial deviations from uncovered interest parity, with investors demanding higher compensation for foreign currency risk.

Finally, the U.S. risk-free rate declines over the medium term, though the impact effect is largely muted. This result is particularly important theoretically: most models featuring financial frictions predict rising safe rates after uncertainty shocks, but we observe the opposite in the data.[6]

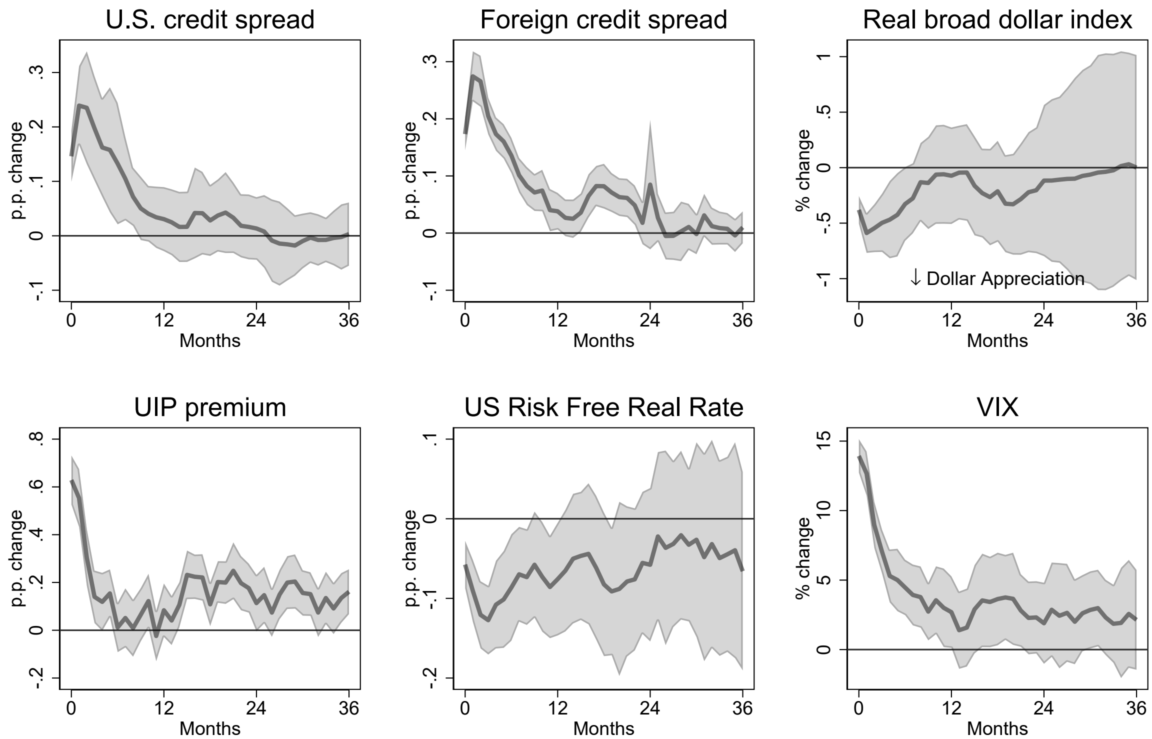
These results collectively demonstrate that U.S. uncertainty shocks have large, synchronized effects on global financial conditions, with particularly strong impacts on risk premia and international arbitrage conditions. In Section 4, we show that our model with global financial intermediaries can replicate these empirical patterns.[7]

[5] Our panel data sample excludes countries and time periods during which countries in the sample had fixed exchange rate regimes, based on the exchange rate classification provided in Ilzetzki et al. (2017). The list of countries is presented in Table A.1 in the Appendix. Note also that the UIP premium is measured using short-term deposit and money market interest rates, i_t, spot exchange rates, s_t, and expectations of exchange rates obtained from Consensus Forecasts survey data, s^e_{t+h} based on the formula: $UIP_{t+h} = (i_t - i^{US}_t) - (s^e_{t+h} - s_t)$, where h is 12 months, as in Kalemli-Ozcan (2019) and Kalemli-Ozcan and Varela (2021). Data sources are listed in Table A.2 in the Appendix.

[6] It is not shown in the figure, but splitting the foreign countries between the emerging and advanced economies, we find that the shock has larger effects on emerging market corporate credit spreads and also on UIP risk premia for holding emerging market currencies.

[7] In Appendix C we present some motivating evidence on the role of global banks' equity positions to transmit

Figure 2: Responses to uncertainty shock, data



Note: Impulse response to a U.S. uncertainty shock in the data. UIP refers to uncovered interest rate parity that is measured using deposit and money market interest rates and expectations of exchange rates from Consensus Forecast. Credit spreads, UIP premia and the real interest rates are in percentage points change. Real broad dollar index and VIX are in percent change. We used monthly data from 1990 to 2024. The shaded areas denote 95 percent confidence intervals that control for HAC.

3 Model

Our framework is an open-economy extension of a standard exchange economy as in Lucas (1978), augmented to allow for the presence of financially constrained intermediaries that operate globally. There are two countries: the home economy, which we interpret as the United States, and a foreign country. Foreign-economy variables are denoted by *. While it would be straightforward to extend the model to incorporate endogenous production, focusing on an endowment economy keeps the analysis transparent. Accordingly, in each country there is fixed aggregate supply of capital ("trees") that produce a stochastic amount of output ("fruit") each period. The productivity of capital, Z_t, follows an exogenous stochastic process that is uncorrelated across countries. In addition, the volatility of future realizations of home productivity Z_t is time-varying. Uncertainty shocks are modeled as fluctuations in this volatility, denoted $\sigma_{z,t}$.

The presence of financially constrained intermediaries is central to the framework. We model

those shocks across the borders.

U.S.-based intermediaries that specialize in holding and intermediating both domestic and foreign capital, as well as foreign government bonds. These intermediaries are assumed to have greater expertise than households in managing capital. Intermediaries finance their asset positions by issuing deposits to U.S. households, but their ability to do so is limited by a financial friction arising from limited enforcement, which gives rise to an endogenous leverage constraint. Households can also hold risky capital, but they do so less efficiently than intermediaries. We capture this inefficiency through management costs that households incur when holding these assets.

There are three types of agents in this economy: U.S. households, U.S. financial intermediaries, and foreign households. We begin by describing the evolution of aggregate productivity in each country and then describe the behavior of each type of agent.

3.1 Aggregate productivity

Aggregate capital in each country is exogenous, and its aggregate supply is normalized to unity. Capital's productivity is exogenous and given by random variable Z_t, which follows the stochastic process

$$Z_t = (1 - \rho_z) + \rho_z Z_{t-1} + \sigma_{z,t-1}\varepsilon_{z,t}, \tag{4}$$

with

$$\sigma_{z,t} = (1 - \rho_\sigma)\overline{\sigma}_z + \rho_\sigma \sigma_{z,t-1} + \varepsilon_{\sigma,t}, \tag{5}$$

where $\varepsilon_{z,t}$ and $\varepsilon_{\sigma,t}$ are *iid* innovations. A positive realization of $\varepsilon_{\sigma,t}$ increases uncertainty about future capital productivity.[8] Foreign productivity, Z_t^*, follows the stochastic process

$$Z_t^* = (1 - \rho_z) + \rho_z Z_{t-1}^* + \overline{\sigma}_z^* \varepsilon_{z,t}^*, \tag{6}$$

where ε_{zt}^* is an *iid* innovation (and is thus uncorrelated with $\varepsilon_{z,t}$).

3.2 U.S. households

Households in the home country (the U.S.) choose consumption and savings. They save by either depositing funds with financial intermediaries or by holding capital directly. The representative household maximizes

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(\frac{C_{t+j}^{1-\varrho} - 1}{1 - \varrho} - \frac{\alpha}{1+\eta} K_{H,t+j}^{1+\eta} \right), \tag{7}$$

[8]The formulation of uncertainty fluctuations is similar to the one used by Basu and Bundick (2017). As in that paper, we specify the stochastic processes in levels rather than logs to avoid the volatility shock from impacting the level of productivity through Jensen's inequality.

where C_t is a Cobb-Douglas aggregate of a home-produced good, $C_{H,t}$, and a foreign-produced one, $C_{F,t}$, given by

$$C_t = \left(\frac{C_{H,t}}{\omega}\right)^{\omega}\left(\frac{C_{F,t}}{1-\omega}\right)^{(1-\omega)}, \tag{8}$$

and $K_{H,t}$ denotes the amount of capital stock directly held by households. The term $-\frac{\alpha}{1+\eta}K_{H,t}^{1+\eta}$ in households' preferences captures the costs they incur when managing capital directly. As we discuss later, bankers, in contrast, do not incur these management costs. In this way the setup captures households' inferior expertise relative to bankers in monitoring investment projects and generally managing risky private securities. We follow Krishnamurthy and Vissing-Jorgensen (2012) in assuming that these costs are borne in utility terms. The parameters α and η govern the level and curvature of households' management costs. The parameter $\omega \in (0.5, 1]$ governs home bias in consumption preferences.

The household's budget constraint is

$$\frac{P_{H,t}}{P_t}C_{H,t} + \frac{P_{F,t}}{P_t}C_{F,t} + Q_t K_{H,t} + D_t \leq (\frac{P_{H,t}}{P_t}Z_t + Q_t)K_{H,t-1} + R_{t-1}D_{t-1} + T_t \tag{9}$$

for each t, where $P_t = P_{H,t}^{\omega}P_{F,t}^{1-\omega}$ is the consumer price index and $P_{H,t}$ and $P_{F,t}$ denote the prices of the domestically produced and imported goods, respectively. The variable Q_t is the price of domestic capital, expressed in units of the domestic basket. The variable D_t denotes deposits held with domestic intermediaries, also in units of the domestic basket, and R_{t-1} is the gross safe interest rate paid on these deposits between $t-1$ and t. The variable T_t represents net transfers from bankers.

The first-order condition of the households' optimization problem governing the choice between home- and foreign-produced goods are static and can be written, respectively, as:

$$C_{H,t} = \omega\left(\frac{P_{H,t}}{P_t}\right)^{-1}C_t, \tag{10}$$

$$C_{F,t} = (1-\omega)\left(\frac{P_{F,t}}{P_t}\right)^{-1}C_t. \tag{11}$$

We can use the result $P_tC_t \equiv P_{H,t}C_{H,t} + P_{F,t}C_{F,t}$ to re-write the budget constraint as:

$$C_t + Q_tK_{H,t} + D_t \leq (\frac{P_{H,t}}{P_t}Z_t + Q_t)K_{H,t-1} + R_{t-1}D_{t-1} + T_t. \tag{12}$$

The first-order conditions for capital holdings, $K_{H,t}$, and deposits, D_t, are given by

$$\beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\varrho}\right]R_t = 1, \tag{13}$$

$$\beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\varrho}(\frac{P_{H,t+1}}{P_{t+1}}Z_{t+1} + Q_{t+1})\right] = \alpha\frac{K_{H,t}^{\eta}}{C_t^{-\varrho}} + Q_t. \tag{14}$$

The representative household contains a set of bankers who run financial intermediaries and manage global assets through these intermediaries. We describe these intermediaries next.

3.3 U.S. financial intermediaries

We model the existence of financial intermediaries in a way that helps preserve the representative agent paradigm, as originally developed in Gertler and Kiyotaki (2010). Thus, each U.S. household contains a constant measure f of bankers, each of whom manages a financial intermediary and transfers his or her earnings to the household. There is exogenous entry into and exit from the banking sector. Any banker active in period t continues into period $t+1$ with exogenous probability σ. With the complementary probability the banker exits, upon which he or she rebates any earnings to the household. At the same time, non-banker household members become bankers in period t with probability $(1-\sigma)\frac{f}{1-f}$, so that a measure $(1-\sigma)f$ of new bankers enter each period, exactly offsetting the number that exited. New bankers receive an equity endowment from the household to start operations.

U.S. financial intermediaries operate globally: They hold foreign private securities and foreign government bonds, in addition to domestic private securities. Accordingly, we think of these institutions as "global banks." Each intermediary, indexed by i, holds domestic capital $K_{B,i,t}$ and foreign capital $K^*_{B,i,t}$ (where "B" denotes quantities held by banks, as opposed to households). Intermediaries also hold government bonds $B^*_{B,i,t}$, denominated in terms of the foreign basket. They finance these asset holdings by issuing deposits to households, $D_{i,t}$, and with their own net worth, $N_{i,t}$. Intermediary i's balance sheet identity is therefore

$$Q_t K_{B,i,t} + Q^*_t K^*_{B,i,t} + \mathcal{S}_t B^*_{B,i,t} = D_{i,t} + N_{i,t}, \tag{15}$$

where Q^*_t is the price of foreign capital (in terms of the domestic basket) and $\mathcal{S}_t$ is the real exchange rate, defined as the price of the foreign consumption basket in terms of the home basket:

$$\mathcal{S}_t = \frac{P^*_t}{P_t}. \tag{16}$$

For a continuing banker, the budget constraint states that the bank's expenditures (consisting of asset purchases, both at home and abroad, and repayment on debt obtained from domestic households) cannot exceed its revenues (stemming from new financing raised from households and payments obtained from previous-period capital and bond holdings):

$$\begin{aligned} Q_t K_{B,i,t} + Q^*_t K^*_{B,i,t} + \mathcal{S}_t B^*_{B,i,t} + R_{t-1} D_{i,t-1} \leq\ & D_{i,t} + \left(\frac{P_{H,t}}{P_t} Z_t + Q_t\right) K_{B,i,t-1} \\ & + \left(\frac{P_{F,t}}{P_t} Z^*_t + Q^*_t\right) K^*_{B,i,t-1} + \mathcal{S}_t R^*_{t-1} B^*_{B,i,t-1}, \end{aligned} \tag{17}$$

where R^*_t denotes the foreign risk-free gross interest rate paid by the foreign country.

Combining equations (15) and (17) we obtain the net worth evolution equation:

$$N_{i,t} = (\frac{P_{H,t}}{P_t}Z_t + Q_t)K_{B,i,t-1} + (\frac{P_{F,t}}{P_t}Z_t^* + Q_t^*)K_{B,i,t-1}^* + \mathcal{S}_t R_{t-1}^* B_{B,i,t-1}^* - R_{t-1}D_{i,t-1}. \quad (18)$$

The banker's objective is to maximize the expected value of its payout to the household:

$$V_{i,t} = \mathbb{E}_t \left[\sum_{j=1}^{\infty} \Lambda_{t,t+j}(1-\sigma)\sigma^{j-1} N_{i,t+j} \right] \quad (19)$$

$$= \mathbb{E}_t \left\{ \Lambda_{t,t+1} \left[(1-\sigma)N_{i,t+1} + \sigma V_{i,t+1} \right] \right\}, \quad (20)$$

where

$$\Lambda_{t,t+j} \equiv \beta \left(\frac{C_{t+j}}{C_t} \right)^{-\varrho} \quad (21)$$

denotes the household's stochastic discount factor. We shall assume non-negativity constraints for capital holdings: $K_{B,i,t} \geq 0$, $K_{B,i,t}^* \geq 0$. In addition to non-negativity, maximization of (20) is subject to two constraints: the net worth evolution (18), and an incentive constraint that arises from an agency friction between the banker and its creditors. That friction takes the form of a limited enforcement problem, following Gertler and Kiyotaki (2010): after borrowing funds, the banker can renege on the obligations to depositors and instead divert a fraction θ of the assets he or she owns. Depositors can still recover fraction $1-\theta$ of assets in bankruptcy proceedings. We assume that only private securities are at risk of being diverted. The motivation for that assumption is that private securities are hard to monitor by depositors and are therefore an easier target for bankers to divert than government bonds, which require little or no monitoring. The resulting incentive constraint puts an endogenous limit on how much creditors are willing to allow the banker to lever up in the first place. The banker's incentive constraint is

$$V_{i,t} \geq \theta \left(Q_t K_{B,i,t} + Q_t^* K_{B,i,t}^* \right), \quad (22)$$

where the parameter θ denotes the fraction that can be diverted, and thus serves as a natural index of the degree of financial frictions. The constraint states that the value of misbehaving cannot exceed the value of operating honestly.

We solve the banker's problem by undetermined coefficients. We begin by guessing that the value function is linear: $V_{i,t} = \Psi_t N_{i,t}$, where Ψ_t is non-bank-specific. To that end, we first define the following ratios of asset values to net worth: $\phi_t \equiv \frac{Q_t K_{B,i,t}}{N_{i,t}}$, $\phi_t^* \equiv \frac{Q_t^* K_{B,i,t}^*}{N_{i,t}}$, and $\phi_{B,t}^* \equiv \frac{\mathcal{S}_t B_{B,i,t}^*}{N_{i,t}}$. All three ratios will turn out to be independent of banker-specific variables, so we omit the i subscript in anticipation of that result.

The banker's problem can then be expressed as:

$$\Psi_t = \max_{\phi_t, \phi_t^*, \phi_{B,t}^*} \quad \phi_t \mu_t + \phi_t^* \mu_t^* + \phi_{B,t}^* \mu_{B,t}^* + \nu_t \quad (23)$$

subject to

$$\phi_t \mu_t + \phi_t^* \mu_t^* + \phi_{B,t}^* \mu_{B,t}^* + \nu_t \geq \theta \left(\phi_t + \phi_t^* \right), \tag{24}$$

where the variables ν_t, μ_t, μ_t^*, and $\mu_{b,t}^*$ are given by

$$\nu_t = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}]R_t, \tag{25}$$

$$\mu_t = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}(R_{k,t+1} - R_t)], \tag{26}$$

$$\mu_t^* = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}(R_{k,t+1}^* - R_t)], \tag{27}$$

$$\mu_{B,t}^* = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}(\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t} R_t^* - R_t)], \tag{28}$$

with $R_{k,t+1} \equiv \frac{\frac{P_{H,t+1}}{P_{t+1}} Z_{t+1} + Q_{t+1}}{Q_t}$, $R_{k,t+1}^* \equiv \frac{\frac{P_{F,t+1}}{P_{t+1}} Z_{t+1}^* + Q_{t+1}^*}{Q_t^*}$, and

$$\Omega_{t+1} \equiv 1 - \sigma + \sigma \Psi_{t+1}. \tag{29}$$

The variable ν_t can be thought of as the marginal cost of deposits, and the variables $\mu_t, \mu_t^*, \mu_{B,t}^*$ as the excess marginal value of each type of asset (domestic capital, foreign capital, and foreign bonds, respectively) over deposits. Importantly, note that the discount factor the banker uses to evaluate payoffs in $t+1$ is given by the household's discount factor, $\Lambda_{t,t+1}$, multiplied by Ω_{t+1}. The latter corresponds to a weighted average of the marginal value of a unit of net worth in $t+1$: with probability $1-\sigma$, the banker exits in $t+1$, in which case the marginal value of a unit of net worth is simply unity; with probability σ, the banker continues operating a financial intermediary, in which case the value of a unit of net worth is given by Ψ_{t+1}. Because of the banker's financing constraint, this value typically exceeds unity. Moreover, it tends to be strongly countercyclical, as the constraint becomes particularly tight in bad times. As we discuss below, this feature plays an important role in shaping the transmission of uncertainty shocks.

In an interior equilibrium with positive capital holdings by intermediaries, the following condition must hold:

$$\mu_t = \mu_t^*, \tag{30}$$

The intuition for this condition is straightforward: In an equilibrium in which the banker holds both domestic and foreign capital, their expected discounted returns must be equalized—because if they were not, the banker could reallocate resources from the asset with the lower expected return to higher-return asset, raising expected profits.

The following condition must also hold:

$$\mu_{B,t}^* = 0, \tag{31}$$

stating that bankers make zero expected discounted excess returns on foreign government bonds. That result arises because foreign government bonds are not subject to diversion by bankers, and therefore are not affected by the limits to arbitrage implied by the financial constraint. Note, however, that the discount factor appearing in this no-arbitrage condition is the banker's, and therefore includes the marginal value of net worth, Ω_{t+1}.

As long as the total excess return μ_t satisfies $0 < \mu_t < \theta$, the incentive constraint (24) binds. It follows that the banker's total leverage on risky assets, $\phi_t + \phi_t^*$, satisfies

$$\phi_t + \phi_t^* = \frac{\nu_t}{\theta - \mu_t}, \tag{32}$$

confirming that leverage is independent of banker-specific variables. Thus, the incentive constraint puts an upper limit on banker leverage, given by (32). The tightness of that limit depends positively on the fraction of securities the banker can divert, θ, and depends negatively on the excess value of capital, $\mu_t = \mu_t^*$, as higher values of the latter raise the franchise value of the bank thus diminishing the incentives to divert funds. From (23), Ψ_t is then given by

$$\Psi_t = \phi_t \mu_t + \phi_t^* \mu_t^* + \nu_t. \tag{33}$$

Turning to aggregation, we let $K_{B,t} \equiv \int_0^f K_{B,i,t} di$, $K_{B,t}^* \equiv \int_0^f K_{B,i,t}^* di$, $N_t \equiv \int_0^f N_{i,t} di$. Given that ϕ_t and ϕ_t^* are independent of bank-specific factors, these aggregates satisfy

$$Q_t K_{B,t} = \phi_t N_t, \tag{34}$$

$$Q_t^* K_{B,t}^* = \phi_t^* N_t. \tag{35}$$

If banker i is a new entrant, we assume he or she receives an endowment given by fraction $\frac{\xi}{f}$ of the value of total asset holdings in the previous period. Accordingly, the evolution of aggregate net worth N_t is

$$\begin{aligned} N_t = \sigma \Big[&(R_{k,t} - R_{t-1}) Q_{t-1} K_{B,t-1} + (R_{k,t}^* - R_{t-1}) Q_{t-1}^* K_{B,t-1}^* + \left(\frac{\mathcal{S}_t}{\mathcal{S}_{t-1}} R_{t-1}^* - R_{t-1} \right) \mathcal{S}_{t-1} B_{B,t-1}^* \\ &+ R_{t-1} N_{t-1} \Big] + (1-\sigma) \xi \left[Q_{t-1} K_{B,t-1} + Q_{t-1}^* K_{B,t-1}^* + \mathcal{S}_{t-1} B_{B,t-1}^* \right] \end{aligned} \tag{36}$$

where

$$B_{B,t}^* \equiv \int_0^f B_{B,i,t}^* di = \phi_{B,t}^* N_t. \tag{37}$$

3.4 Foreign households

Households in the foreign country consume and save through holdings of capital and government bonds. We do not explicitly model foreign financial intermediaries, and instead assume that their rule is subsumed within the foreign household sector. Foreign households can invest in foreign capital and foreign government bonds—both of which entail management costs, like for U.S. households.

However, we assume that foreign households cannot invest in U.S. capital (unlike U.S. intermediaries, which, as discussed above, can hold both foreign capital and foreign government bonds). We view this asymmetry as reflecting the greater financial development of the United States, which allows its financial system to operate globally, unlike its foreign counterpart.

The foreign representative household consumes and saves via foreign capital holdings, $K^*_{H,t}$, and holdings of foreign risk-free government bonds, $B^*_{H,t}$. Its objective is to maximize

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(\frac{(C^*_{t+j})^{1-\varrho} - 1}{1-\varrho} - \frac{\alpha^*}{1+\eta^*} (K^*_{H,t+j})^{1+\eta^*} - \frac{\alpha^*_b}{2} (B^*_{H,t+j})^2 \right) \tag{38}$$

where C^*_t is a Cobb-Douglas aggregate of the foreign-produced good, $C^*_{F,t}$, and the home-produced one, $C^*_{H,t}$:

$$C^*_t = \left(\frac{C^*_{F,t}}{\omega} \right)^{\omega} \left(\frac{C^*_{H,t}}{1-\omega} \right)^{(1-\omega)}. \tag{39}$$

As for U.S. households, the preference terms involving $K_{H,t}$ and $B^*_{H,t}$ capture foreign households' relative inefficiency in managing these assets.

The budget constraint is:

$$P^*_{F,t} C^*_{F,t} + P^*_{H,t} C^*_{H,t} + \frac{P^*_t Q^*_t}{\mathcal{S}_t} K^*_{H,t} + P^*_t B^*_{H,t} \leq \left(P^*_{F,t} Z^*_t + \frac{P^*_t Q^*_t}{\mathcal{S}_t} \right) K^*_{H,t-1} + P^*_t R^*_{t-1} B^*_{H,t-1} + P^*_t T^*_t, \tag{40}$$

where P^*_t is the foreign consumer price index, and $P^*_{F,t}$ and $P^*_{H,t}$ are the prices of the foreign and U.S. good abroad, respectively. The variable Q^*_t is the *dollar* price of claims on home capital. The variable R^*_{t-1} is the safe interest rate between $t-1$ and t, and T^*_t is net transfers to foreign households.

The first-order conditions for households' choice between home- and foreign-produced goods are:

$$C^*_{H,t} = (1-\omega) \left(\frac{P^*_{H,t}}{P^*_t} \right)^{-1} C^*_t, \tag{41}$$

$$C^*_{F,t} = \omega \left(\frac{P^*_{F,t}}{P^*_t} \right)^{-1} C^*_t, \tag{42}$$

where

$$P^*_t = (P^*_{F,t})^{\omega} (P^*_{H,t})^{1-\omega}. \tag{43}$$

As before, we can use the result $P^*_t C^*_t = P^*_{F,t} C^*_{F,t} + P^*_{H,t} C^*_{H,t}$ to rewrite the budget constraint in real terms:

$$C^*_t + \frac{Q^*_t}{\mathcal{S}_t} K^*_{H,t} + B^*_{H,t} \leq \left(\frac{P^*_{F,t}}{P^*_t} Z^*_t + \frac{Q^*_t}{\mathcal{S}_t} \right) K^*_{H,t-1} + R^*_{t-1} B^*_{H,t-1} + T^*_t. \tag{44}$$

The dynamic first-order conditions of the foreign households' optimization problem are:

$$\beta \mathbb{E}_t \left[\left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\varrho} \right] R^*_t = \alpha^*_b \frac{(B^*_{H,t})}{(C^*_t)^{-\varrho}} + 1, \tag{45}$$

$$\beta \mathbb{E}_t \left[\left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\varrho} \left(\frac{P^*_{F,t+1}}{P^*_{t+1}} Z^*_{t+1} + \frac{Q^*_{t+1}}{\mathcal{S}_{t+1}} \right) \right] = \alpha^* \frac{(K^*_{H,t})^{\eta^*}}{(C^*_t)^{-\varrho}} + \frac{Q^*_t}{\mathcal{S}_t}. \tag{46}$$

3.5 Terms of trade, real exchange rate, and market clearing

We assume that the law of one price holds: $P_{H,t} = P^*_{H,t}$ and $P_{F,t} = P^*_{F,t}$. Let the terms of trade be defined as $\mathcal{T}_t \equiv P_{F,t}/P_{H,t}$ (the price of home imports relative to the price of home exports). Given the expressions for the price levels P_t and P^*_t described previously, it is straightforward to show that $\mathcal{T}_t$ and $\mathcal{S}_t$ satisfy

$$\mathcal{S}_t = \mathcal{T}_t^{2\omega-1}. \tag{47}$$

Using the law of one price and the expressions for P_t and P^*_t, all relative prices (such as $P_{H,t}/P_t$) can be expressed as functions of the terms of trade. Equilibrium can therefore conveniently be characterized in terms of the two relative prices $\mathcal{T}_t$ and $\mathcal{S}_t$, which are linked by condition (47).

There are five markets: for home and foreign goods, for home and foreign capital, and for foreign government bonds. We normalize the supply of both domestic and foreign capital to unity, and assume that the foreign government bond is in zero net supply. Accordingly, the market-clearing conditions associated with these five markets are, respectively:

$$C_{H,t} + C^*_{H,t} = Z_t, \tag{48}$$

$$C_{F,t} + C^*_{F,t} = Z^*_t, \tag{49}$$

$$K_{H,t} + K_{B,t} = 1, \tag{50}$$

$$K^*_{H,t} + K^*_{B,t} = 1, \tag{51}$$

$$B^*_{H,t} + B^*_{B,t} = 0. \tag{52}$$

Given the above, combining U.S. households' and global banks' budget constraints we get the following balance of payments identity:

$$C_t + Q^*_t(K^*_{B,t} - K^*_{B,t-1}) + \mathcal{S}_t(B^*_{B,t} - R^*_{t-1} B^*_{B,t-1}) = \frac{P_{H,t}}{P_t} Z_t + \frac{P_{F,t}}{P_t} Z^*_t K^*_{B,t-1} \tag{53}$$

Equilibrium is then characterized by the equations above as follows. The 13 endogenous variables pertaining to global banks $\left\{ N_t, \Omega_t, \nu_t, \mu_t, \mu^*_t, \mu^*_{B,t}, \phi_t, \phi^*_t, K_{B,t}, K^*_{B,t}, B^*_{B,t}, Q_t, Q^*_t \right\}$, together with the 5 variables pertaining to home households $\{C_{F,t}, C_{H,t}, C_t, K_{H,t}, R_t\}$, the 6 variables pertaining to the foreign economy $\left\{ C^*_{F,t}, C^*_{H,t}, C^*_t, K^*_{H,t}, R^*_t, B^*_{H,t} \right\}$, and the terms of trade and real exchange rate $\{\mathcal{T}_t, \mathcal{S}_t\}$, are together determined by 26 equations: (10)-(11), (13)-(14), (25)-(32), (34)-(36), (41)–(42), (45)-(47), and (48)–(53). We present the complete set of equilibrium conditions in Appendix D.

3.6 Measurement of observables

We will consider below the model's predictions for the observables studied in Section 2. We take the model counterpart of the corporate borrowing spread to be the difference between the return on capital and the risk-free rate, adjusting for the fact that corporate bonds in the data have a duration of about five years. Similarly, we construct a model-implied long safe rate by cumulating expected short rates over the corresponding horizon. We also construct model counterparts of the UIP premium and the VIX using definitions consistent with those in the data (recall that the UIP premium we use is constructed with a one-year horizon). The resulting model counterparts of these empirical objects are (where lowercase letters denote logarithms):

$$\text{spread}_{\text{us},t} = \frac{1}{20}\sum_{j=0}^{19}\mathbb{E}_t[r_{k,t+1+j} - r_{t+j}], \tag{54}$$

$$\text{spread}_{\text{for},t} = \frac{1}{20}\sum_{j=0}^{19}\mathbb{E}_t[r^*_{k,t+1+j} - r_{t+j}], \tag{55}$$

$$\text{uip\_premium}_t = \frac{1}{4}\sum_{j=0}^{3}\left(r^*_{t+j} - r_{t+j} + \mathbb{E}_t[s_{t+j+1}] - s_{t+j}\right), \tag{56}$$

$$\text{safe\_rate}_{\text{us},t} = \frac{1}{40}\sum_{j=0}^{39} r_{t+j}, \tag{57}$$

$$\text{vix}_t = 100 \times \sqrt{4 \times \text{Var}_t(r_{k,t+1})}. \tag{58}$$

3.7 Solution method and calibration

Our primary focus is on examining the effects of an increase in the second moment of U.S. capital's productivity process, driven by $\sigma_{z,t}$. To that end, we follow Basu and Bundick (2017) and Fernández-Villaverde et al. (2011) and solve the model using a third-order approximation around the deterministic steady state. A third-order approximation is required to capture the effects of time variation in second moments of exogenous shocks. We implement the solution using the Dynare software package.

Table 1 lists the choice of parameter values for our model. The household discount factor, β, and risk aversion, ϱ, are set to conventional values. We calibrate the home bias parameter, ω, to 0.94, consistent with the U.S. import share of consumption of about 6 percent.

We set the parameter governing home households' capital management cost, α, so that home households hold fifty percent of home capital in steady state, with the remaining fifty percent held by financial intermediaries, consistent with the evidence presented in GK of a roughly 50/50 split of U.S private assets held by leveraged and non-leveraged institutions. We set α^*, the parameter governing foreign households' management costs of capital, to yield a split of foreign capital holdings in which two-thirds of foreign capital are held by foreign residents and one-third is held by home residents. The resulting ratio of foreign assets held by home residents to home GDP is 100 percent,

Table 1: Parameter Values

Parameter	Description	Value
Household preferences		
β	Discount factor	0.99
ϱ	Risk aversion	4
ω	Home bias	0.94
Household financial technology		
α	Capital management cost, home	36
α^*	Capital management cost, foreign	40
α_b^*	Bond management cost	0.225
η	Curvature in capital management cost	8
Global banks		
σ	Survival probability	0.95
ξ	New banker endowment	0.1
θ	Divertable share	0.29
Shock processes		
ρ_z	Autocorr. productivity shock	0.90
ρ_σ	Autocorr. uncertainty shock	0.80
$\overline{\sigma}_z$	Avg. SD of home productivity	0.013
$\overline{\sigma}_z^*$	SD of foreign productivity	0.006

which is roughly in line with the ratio of the sum of U.S. holdings of foreign direct investment and portfolio investment to U.S. GDP reported by the BEA. The parameter governing foreign households' cost of managing foreign government bonds, α_b^*, has quantitatively large implications for the volatility of $B_{B,t}^*$, making that volatility a natural target in its calibration. We thus set α_B^* to generate a standard deviation of the ratio of $\Delta B_{B,t}^*$ to home GDP of 0.022, matching the standard deviation of U.S. net acquisitions of foreign portfolio debt assets relative to U.S. GDP. We set the curvature of the management cost function, η, so that the model matches an average UIP premium on foreign currencies of about 2.5 percent in our data (including expectations of future risk). The parameter η helps inform this moment because it determines the extent to which global banks' stochastic discount factor matters in pricing assets, as we discuss in detail below.

Turning to the parameters related to global banks, we set the survival probability, σ, to 0.95, a value around the midpoint of the range found in related work, and consistent with a five percent dividend payout ratio as in Gertler and Kiyotaki (2015). We then set the parameter governing new bankers' endowment, ξ, and the divertable fraction of risky assets, θ, to simultaneously hit two steady-state targets: a bank leverage ratio of five and a U.S. credit spread of 125 basis points. The target leverage ratio roughly matches the estimated global bank leverage ratio reported by Morelli et al. (2022), and the credit spread target matches the average U.S. credit spread in our sample.

Turning to the shock processes, we set the autocorrelation of the productivity shock, ρ_z, to 0.90, implying a highly persistent process, and we set the autocorrelation of the uncertainty shock,

ρ_σ, to match the decay in the VIX from our empirical impulse responses in Section 2. Finally, we set the average standard deviations of the home and foreign productivity shocks, $\overline{\sigma}_z$ and $\overline{\sigma}_z^*$, so that the model matches the standard deviation of U.S. GDP and of an aggregate of foreign GDP constructed by aggregating non-U.S. countries as in Bodenstein et al. (2023)—equal to about 3 percent for the U.S. and 1.3 percent for the foreign block after detrending by a log-linear trend.

4 Model analysis

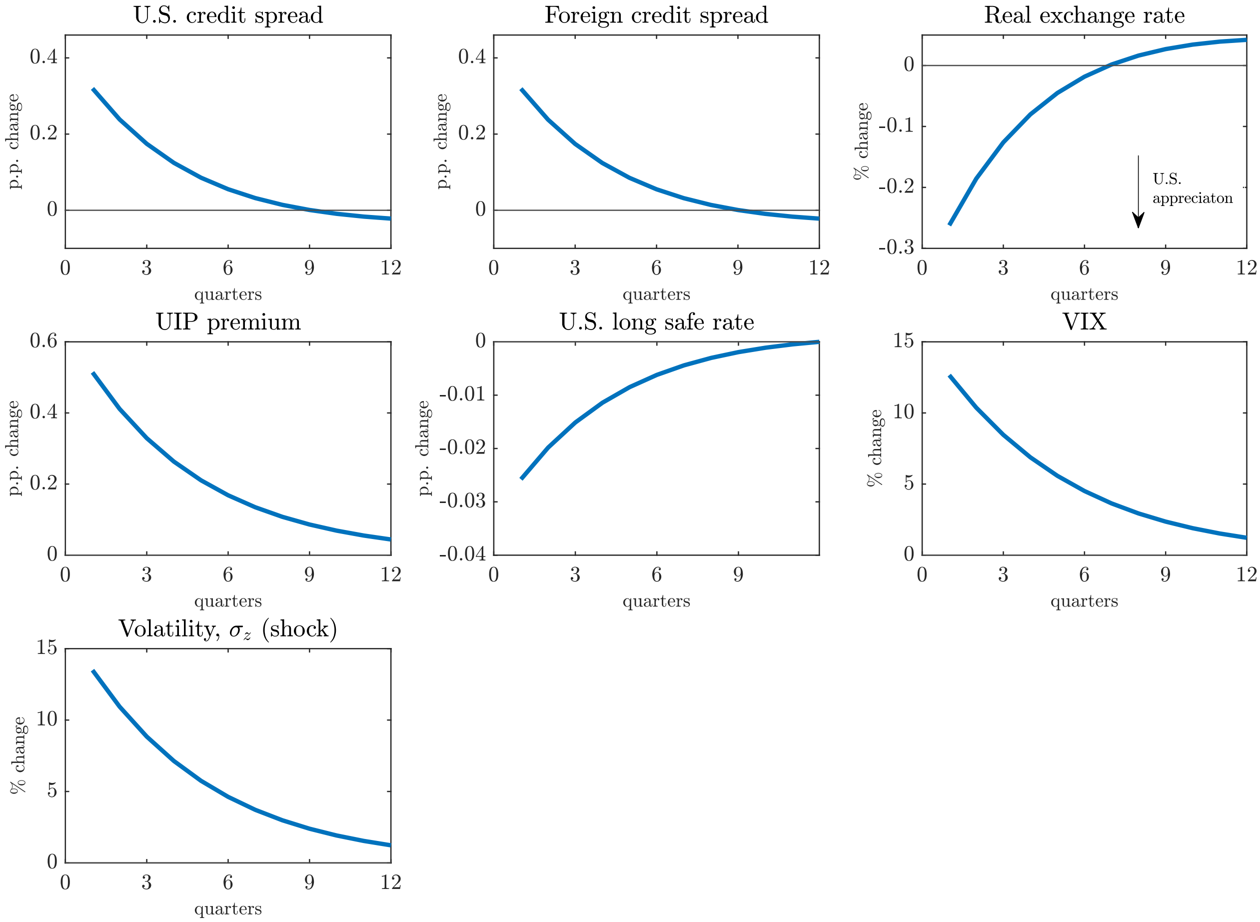
We now turn to a quantitative analysis of the model, focusing on the effects of an increase in the uncertainty of the U.S. endowment, $\sigma_{z,t}$. Figure 3 shows the model-implied counterparts of responses to a higher U.S. uncertainty of the variables shown in Figure 2. We calibrate the size of the uncertainty shock so that the increase in the VIX in the model in the first quarter upon impact is the same as in the data. Note also that the rate of decay in the VIX matches that in the data, with the VIX remaining just under 5 percent above its no-shock path after two years in both the model and the data.

The model closely matches both the magnitudes and the dynamics of global financial variables following an increase in uncertainty. Both U.S. and foreign spreads rise in tandem, by 0.3 percentage points on impact, closely aligning with their empirical counterpart. The dollar appreciates by 0.3 percent, somewhat less than in the empirical exercise, and the UIP premium jumps by 0.5 percentage points, as in the data. We also find that higher uncertainty is associated with a lower U.S. safe rate, again in line with the empirical results documented here as well as elsewhere in the literature. Taken together, these results indicate that despite its simplicity and relatively small number of parameters, the model is able to capture the joint response of global financial variables to an uncertainty shock.

As we elaborate below, a key mechanism behind these results is the interaction between an increase in risk and the role of global financial intermediaries as the marginal pricers of risk, such that their stochastic discount factor governs asset pricing in the model. As we show in detail below, the presence of intermediary leverage constraints and the associated financial accelerator effects make risk premia much more responsive to increases in uncertainty than in a model without intermediation frictions. Additionally, because these intermediaries price both home and foreign risky assets and must in equilibrium be indifferent between holding either, the increase in risk strongly spills over to foreign assets, generating nearly identical responses in foreign and domestic credit spreads, consistent with the data. Further, as we describe in the final subsection, the sharp increase in the UIP premium—driven by heightened sensitivity of currency risk premia under intermediary frictions—leads to a dollar appreciation despite the decline in the home interest rate induced by precautionary savings.

The following subsections further unpack the mechanism and highlight its key components. We do so by considering a series of model simplifications. In the first subsection, we strip down the open-economy dimension and household risky asset holdings. This simplification yields a tractable

Figure 3: Responses to uncertainty shock, model



Note: Responses to an uncertainty shock in the model sized to produce an increase in the VIX in the first quarter of the same size as in the empirical impulse responses shown in Figure 2.

setup to study the interaction between the pricing of risk and intermediary constraints. In the following section, we elaborate on how the risk shock spills over to foreign risky assets. In the final section, we analyze the effects of risk on the exchange rate in the model, contrasting them with those that arise in a canonical two-country, two-good model without global intermediation frictions. [9]

4.1 Inspecting the mechanism: Uncertainty shocks in autarky

We turn now to an autarky version of the model, in which we also assume for simplicity that households hold no capital. We let $\omega = 1$, assume no holdings of foreign capital or bonds by banks,

[9] In Appendix E we show that a first-moment shock cannot match the evidence: First-moment (or non-uncertainty) shocks have very small effects on the expected volatility of future returns, and they lead to increases in the U.S. safe rate. Basu and Bundick (2017) have made a similar argument.

and let $\alpha \to \infty$, implying that all domestic capital is held by banks. Let $g_{z,t+1} \equiv Z_{t+1}/Z_t$ denote the (exogenous) growth rate of output. The resulting economy is characterized by the following equilibrium conditions:

$$1 = \beta \mathbb{E}_t \left[g_{z,t+1}^{-\varrho} \right] R_t, \tag{59}$$

$$\mu_t = \mathbb{E}_t \left[g_{z,t+1}^{-\varrho} \Omega_{t+1} \left(\frac{Z_{t+1} + Q_{t+1}}{Q_t} - R_t \right) \right], \tag{60}$$

$$Q_t = \frac{\mathbb{E}_t \left[g_{z,t+1}^{-\varrho} \Omega_{t+1} \right] R_t}{\theta - \mu_t} N_t, \tag{61}$$

$$N_t = \sigma \left(Z_t + Q_t - R_{t-1} Q_{t-1} + R_{t-1} N_{t-1} \right) + (1-\sigma) \xi Q_{t-1}, \tag{62}$$

where

$$\Omega_{t+1} \equiv 1 - \sigma + \sigma \theta \frac{Q_{t+1}}{N_{t+1}}. \tag{63}$$

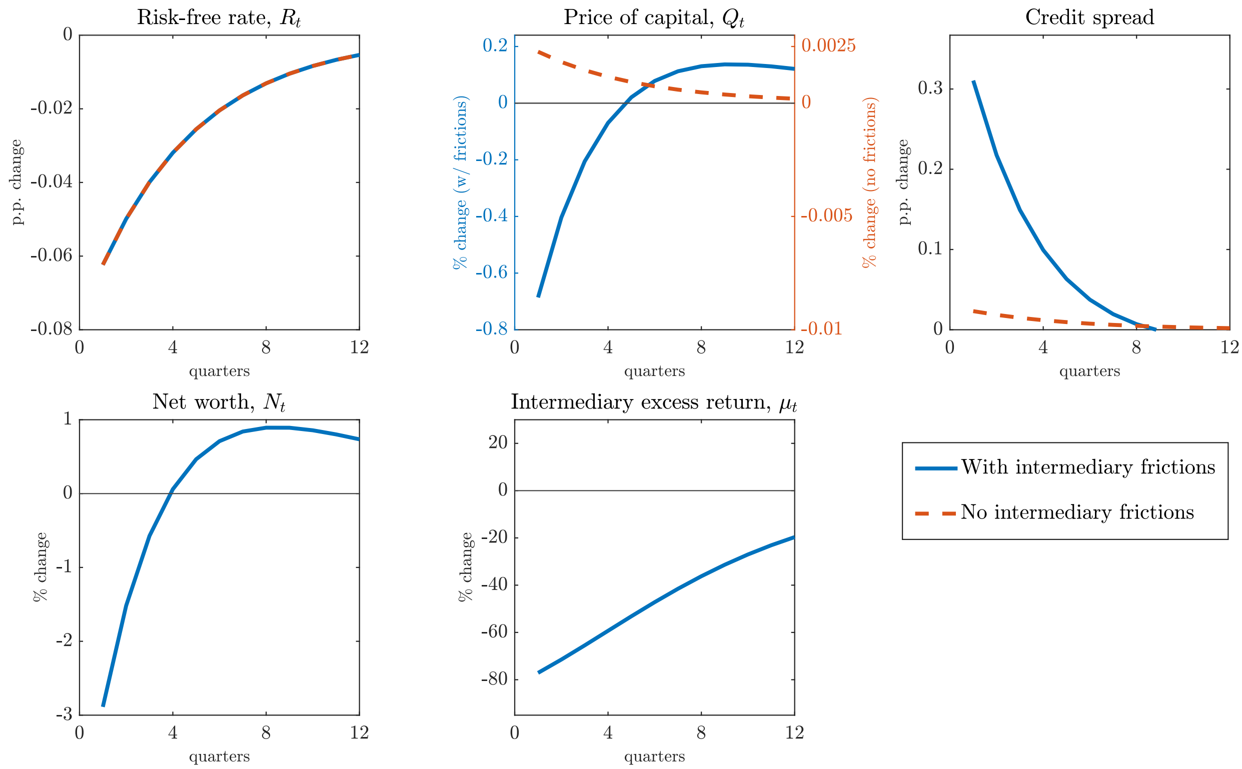
The four equations (59)-(62) determine the four endogenous variables $\{R_t, \mu_t, Q_t, N_t\}$, given the stochastic processes for Z_t and $\sigma_{z,t}$ in (4)-(5). Equation (59) is the Euler equation characterizing optimal household saving, which determines the risk-free rate R_t. Equation (60) defines financial intermediaries' expected discounted excess return μ_t—the prospective return on assets net of the risk-free rate, evaluated using the intermediaries' stochastic discount factor, $g_{z,t+1}^{-\varrho} \Omega_{t+1}$. This discount factor augments the household's marginal utility of consumption in $t+1$ relative to t, given by $g_{z,t+1}^{-\varrho}$, with the marginal value of net worth in the following period, given by (63), where we have used that $\Psi_t = \phi_t \mu_t + \nu_t = \theta \frac{Q_t}{N_t}$ under autarky. In bad times (when Z_t is low), N_t falls relative to Q_t—net worth is scarce. This makes the bankers' SDF strongly countercyclical.

Equation (61) is the intermediaries' incentive constraint at equality—effectively a leverage constraint, with $\frac{\mathbb{E}_t \left[g_{z,t+1}^{-\varrho} \Omega_{t+1} \right] R_t}{\theta - \mu_t}$ giving the maximum leverage banks can take on. Given a binding constraint, the aggregate value of assets (which equals Q_t, since the aggregate supply of capital is fixed at unity) must be equal to leverage multiplied by aggregate net worth. Note that leverage is increasing in μ_t: everything else equal, lower expected excess returns imply a lower continuation value for the bank, raising bankers' incentives to default and thus limiting leverage. Finally, (62) describes the evolution of aggregate net worth, which is given by the realized returns on capital net of payouts on previous-period borrowing, plus the endowment of entering bankers.

Figure 4 shows the effect of an increase in $\sigma_{z,t}$ in this autarkic economy. We size the shock so that it generates an increase in the long-run credit spread of 0.3 percentage points, as in our full model with integration.[10] The prospect of a more-risky future payoff has the effect of lowering the excess return μ_t through a decline in $\mathrm{Cov}_t(g_{z,t+1}^{-\varrho} \Omega_{t+1}, R_{k,t+1} - R_t)$ (with $R_{k,t+1} = (Z_{t+1} + Q_{t+1})/Q_t$),

[10] Matching the increase in the spread requires a smaller shock than in the full model, as a shock of a given size has more powerful effects in this autarkic economy. The reason is that intermediaries benefit from the ability to diversify risk by holding foreign risky assets, and that the presence of household holdings also helps cushion the effects of shocks that adversely affect banks' balance sheets.

Figure 4: Effects of uncertainty shock in autarky



Note: Responses to an uncertainty shock in the autarkic version of the model. The shock is sized to generate an increase in the long-run credit spread of 0.3 percentage points, matching the full model with integration.

which is negative on average and turns more negative when aggregate uncertainty rises. A lower μ_t puts downward pressure on leverage, which through (61) leads to lower Q_t (for a given N_t). In addition, the lower returns associated with the decline in the asset price Q_t work to depress N_t via (62), when then initiates another round of decline in Q_t—this is the standard "financial accelerator" feedback effect between asset prices and net worth.[11] A lower risk-free rate and the associated lower deposit rates, driven by the precautionary effects of higher uncertainty via (59), provide some cushion to banks, and ultimately drive the rise in net worth above its pre-shock value after about a year.

It is useful to contrast the effects described thus far with those that would occur in a frictionless benchmark without intermediary constraints. In that case, perfect arbitrage obtains, and it is straightforward to show that the following two equations hold:

$$1 = \beta \mathbb{E}_t \left[g_{z,t+1}^{-\varrho} \right] R_t, \tag{64}$$

$$Q_t = \beta \mathbb{E}_t \left[g_{z,t+1}^{-\varrho} \left(Z_{t+1} + Q_{t+1} \right) \right], \tag{65}$$

[11] In an extension of the model with endogenous production, the decline in Q_t would cause a contraction in investment and in output.

which determine the endogenous variables $\{R_t, Q_t\}$.[12] These equations constitute a standard Lucas (1978) asset pricing model, and can be used to compute the impact of higher uncertainty $\sigma_{z,t}$ on the asset price Q_t, the risk-free rate R_t, and the risk premium $\mathbb{E}_t[R_{k,t+1} - R_t]$. As is well known (Mehra and Prescott, 1985), such a frictionless setting predicts very small effects of risk for conventional values of ϱ. Figure 4 confirms these earlier findings in the literature: the movements in both the price of capital and the credit spread are orders of magnitude smaller than their counterparts with intermediary frictions. (The behavior of the risk-free rate is identical in both cases, as it is determined by the same equation.)

Notably, the degree of amplification due to constrained intermediaries appears to be much larger for uncertainty shocks than for the typical first-moment shocks analyzed in related literature, such as monetary shocks or capital quality shocks. For example, in Gertler and Karadi (2011) the presence of financial constraints amplifies the responses of investment and asset prices to these shocks by around threefold, relative to a model without financial frictions. In contrast, our results show that the degree of amplification is much larger for uncertainty shocks.

Note also that the effects of higher risk on the price of capital in the frictionless economy have the "wrong" sign: absent intermediary frictions, the price of capital Q_t *rises* with higher risk. To understand this behavior, note that without frictions Q_t satisfies

$$Q_t = \frac{\mathbb{E}_t[Z_{t+1} + Q_{t+1}]}{R_t + \mathrm{Cov}_t\left(-\frac{g_{z,t+1}^{-\varrho}}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}]}, R_{k,t+1}\right)} \tag{66}$$

With higher risk, the covariance term in the denominator rises as agents require a larger premium to hold risky assets, pushing Q_t down. At the same time, the risk-free rate, R_t, falls in response to the increased desire for precautionary savings induced by the rise in consumption risk. The latter effect puts upward pressure on asset prices, and turns out to dominate, leading the price of capital to rise.

We next provide some additional color on the drivers of the risk premium, $\mathbb{E}_t[R_{k,t+1} - R_t]$, in both the economy with frictions and the frictionless one. We begin by rearranging (60) to re-write the risk premium as

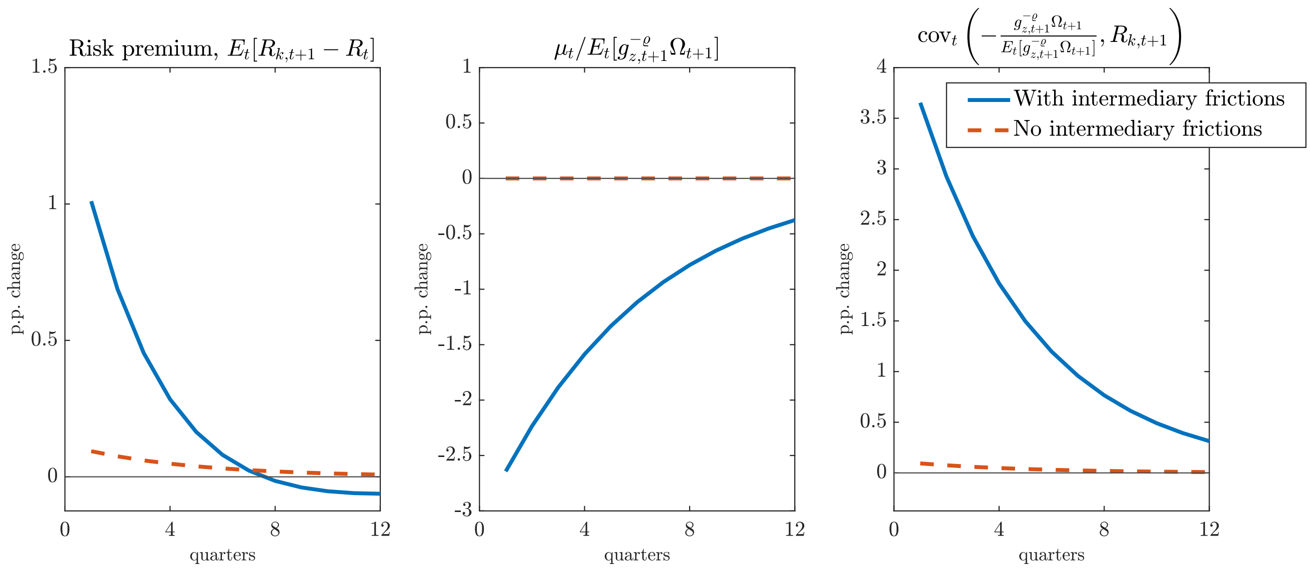
$$\mathbb{E}_t[R_{k,t+1} - R_t] = \frac{\mu_t}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}\Omega_{t+1}]} + \mathrm{cov}_t\left(-\frac{g_{z,t+1}^{-\varrho}\Omega_{t+1}}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}\Omega_{t+1}]}, R_{k,t+1}\right). \tag{67}$$

In the frictionless economy, the same expression for the risk premium holds, except that in that case $\mu_t = 0$ in the first term on the right-hand side, and $\Omega_{t+1} = 1$ in the covariance term.

Figure 5 plots the impulse responses to an increase in uncertainty of the risk premium and its components. In the economy with intermediary frictions, the risk premium jumps by about 1 percentage point on impact, before gradually returning to its pre-shock value. (Note that the

[12]We denote variables in the frictionless benchmark using the same notation as in the model with constraints, as no ambiguity arises within this discussion.

Figure 5: Uncertainty shock in autarky, risk premium decomposition



Note: Responses to an uncertainty shock in the autarkic model, decomposing the risk premium into the excess return μ_t and the covariance term from equation (67).

Table 2: Steady-state risk premium decomposition

	With intermediary frictions	No intermediary frictions
$\text{cov}\left(-\frac{g_{z,t+1}^{-\varrho}\Omega_{t+1}}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}\Omega_{t+1}]}, R_{k,t+1}\right)$	0.104	0.003
Price of risk, $\sigma\left(\frac{g_{z,t+1}^{-\varrho}\Omega_{t+1}}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}\Omega_{t+1}]}\right)$	0.597	0.053
Quantity of risk, $\sigma\left(R_{k,t+1}\right)$	0.175	0.050

magnitude of the increase is much larger than that of the long spread, reflecting that the latter is the forward-cumulative version of the former). The increase in the risk premium occurs despite the decline of about 2.5 percentage points in the (normalized) excess return μ_t, because the covariance between the SDF and the return on capital jumps sharply upward by around 3.5 percentage points—an increase that is an order of magnitude larger than in the frictionless economy.

To provide more intuition on why the effects of the risk correction term are so pronounced in this economy, it is useful to decompose the covariance term in (67) as

$$\text{cov}_t\left(-\frac{g_{z,t+1}^{-\varrho}\Omega_{t+1}}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}\Omega_{t+1}]}, R_{k,t+1}\right) \approx \sigma_t\left(\frac{g_{z,t+1}^{-\varrho}\Omega_{t+1}}{\mathbb{E}_t[g_{z,t+1}^{-\varrho}\Omega_{t+1}]}\right) \times \sigma_t\left(R_{k,t+1}\right), \tag{68}$$

In the asset pricing literature, the standard deviation of the (normalized) SDF (the first term in (68)) is often referred to as the "price" of risk, and the standard deviation of the asset's return (the second term) as the "quantity" of risk. Table 2 provides the decomposition of the covariance into these two components, in both the economy with intermediary frictions and in the economy without.[13] In the economy without intermediary frictions, both the price and quantity of risk are small, making their product even smaller, in line with the results just shown. In the economy with intermediary frictions and the associated financial-accelerator effects, the quantity of risk is notably higher (about three times as large as in the frictionless economy); but the price of risk is over ten times larger. Thus, in the economy with intermediary frictions it is the fact that the marginal value of intermediary wealth fluctuates strongly with the aggregate endowment Z_t—with net worth scarce in bad times, and therefore highly valued, and vice versa in good times—that largely drives the results.

We summarize this section by stressing that the presence of asset pricing by constrained intermediaries leads to (i) large amplification of credit spreads relative to a model without financial intermediation frictions, driven by a much larger risk correction term in this economy than in the frictionless one; and (ii) asset price dynamics following uncertainty shocks that have the correct sign—unlike in the frictionless model.

4.2 Pass-through to foreign risky assets

We now return to our full model and discuss why the effects on foreign credit spreads of an increase in uncertainty about the home endowment are nearly identical to those on domestic spreads themselves. The key equilibrium condition driving this result is (30), which reflects the absence of arbitrage by global banks between home and foreign risky assets. That equation can be re-written as

$$\mathbb{E}_t[\Lambda_{t,t+1}\Omega_{t+1}R_{k,t+1}] = \mathbb{E}_t[\Lambda_{t,t+1}\Omega_{t+1}R^*_{k,t+1}]. \tag{69}$$

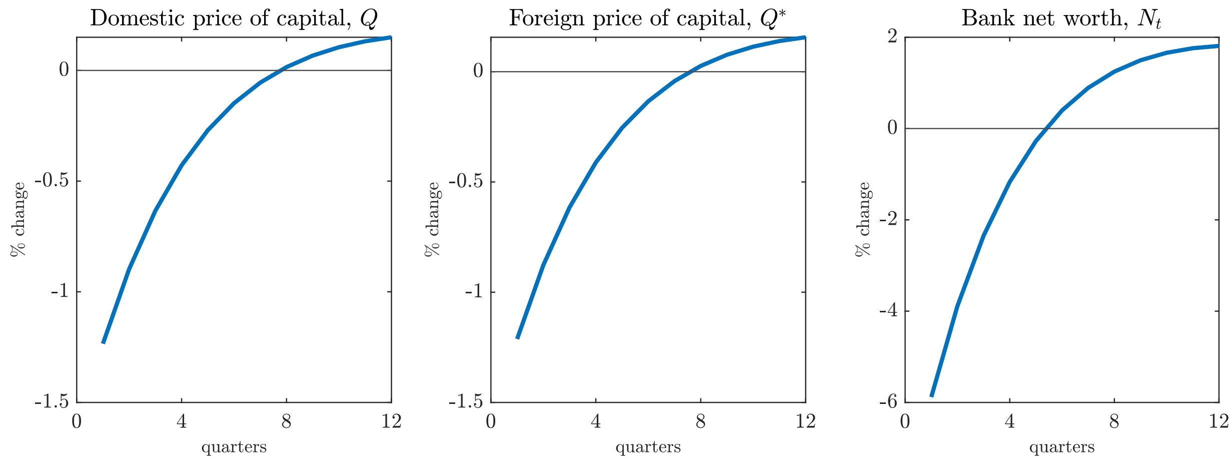
Through this equation, the model implies a tight link between the asset prices Q_t and Q^*_t. To see this, note that to a first order the discount factors vanish from (69); in addition, to the extent that the dividend Z_t is small relative to the price Q_t, as is the case given a discount factor close to unity, a first-order approximation implies that Q_t and Q^*_t move in tandem. It follows that that the risk correction terms driving the effects of the uncertainty shock on credit spreads studied in the previous subsection will apply similarly to foreign as to domestic assets. Accordingly, an increase in uncertainty has similar effects on domestic and foreign risk premia, as shown in Figure 3.

Finally, we note that by a similar argument as in the previous subsection, the full model also implies that both the domestic and foreign price of capital *decline* following an uncertainty shock. The leverage constraint (32), which can be re-written

$$Q_tK_{B,t} + Q^*_tK^*_{B,t} = \frac{\nu_t}{\theta - \mu_t}N_t, \tag{70}$$

[13] We calculate this decomposition in the long-run steady state—the point at which the economy settles absent shocks in our third-order approximation.

Figure 6: Effects of uncertainty shock on price of capital and net worth, full model



Note: Responses to an uncertainty shock in the full model, showing the effects on home and foreign prices of capital (Q_t and Q_t^*) and global bank net worth. The shock size matches that used in Figure 3.

implies that the downward pressure on the leverage limit $\frac{\nu_t}{\theta-\mu_t}$ from higher uncertainty through lower μ_t, puts downward pressure on Q_t and Q_t^*. As a result, these variables fall following an increase in $\sigma_{z,t}$, as shown in Figure 6.

4.3 Exchange rate determination

We now turn to exchange rate dynamics in our model, focusing on the response of exchange rates and deviations from uncovered interest parity (UIP) to an uncertainty shock. We first set the stage by laying out a simple and familiar canonical benchmark that abstracts from intermediation frictions, described in Section 4.3.1. This benchmark serves as a reference point for assessing how global financial intermediation frictions affect exchange rate dynamics. In Section 4.3.2, we then characterize the effects of uncertainty shocks in our model and describe the underlying mechanics, highlighting where our framework differs from the frictionless benchmark.

4.3.1 A canonical benchmark without financial intermediation frictions

We briefly describe an economy with no financial intermediation frictions, without capital holdings, and in which households can hold the non-state-contingent international bond (the only asset in this economy) without incurring portfolio holding costs. What results is a familiar two-country, two-good endowment economy with home bias in preferences, in which the exchange rate is determined by a standard UIP condition. Households maximize $\mathbb{E}_0\left(\sum_{t=0}^{\infty}\beta^t\frac{C_t^{1-\varrho}-1}{1-\varrho}\right)$, with C_t given by (8), subject to the budget constraint

$$\frac{P_{H,t}}{P_t}C_{H,t}+\frac{P_{F,t}}{P_t}C_{F,t}+\mathcal{S}_t(B_t^*-R_{t-1}^*B_{t-1}^*)+B_{H,t}-R_{t-1}B_{H,t-1}\leq\frac{P_{H,t}}{P_t}Z_t, \tag{71}$$

where B_t^* is holdings of the foreign government bond and $B_{H,t}$ is holdings of a home-currency-denominated bond in zero net supply (used to price the domestic interest rate R_t). The exogenous variable Z_t is the endowment of the home good. Following standard steps, equilibrium is characterized by the following conditions:

$$1 = \beta R_t \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\varrho} \right], \tag{72}$$

$$1 = \beta R_t^* \mathbb{E}_t \left[\left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\varrho} \right], \tag{73}$$

$$0 = \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\varrho} \left(\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t} R_t^* - R_t \right) \right], \tag{74}$$

$$C_{H,t} = \omega \mathcal{T}_t^{1-\omega} C_t, \tag{75}$$

$$C_{F,t} = (1-\omega) \mathcal{T}_t^{-\omega} C_t, \tag{76}$$

$$C_{F,t}^* = \omega \mathcal{T}_t^{-(1-\omega)} C_t^*, \tag{77}$$

$$C_{H,t}^* = (1-\omega) \mathcal{T}_t^{\omega} C_t^*, \tag{78}$$

$$Z_t = C_{H,t} + C_{H,t}^*, \tag{79}$$

$$Z_t^* = C_{F,t} + C_{F,t}^*, \tag{80}$$

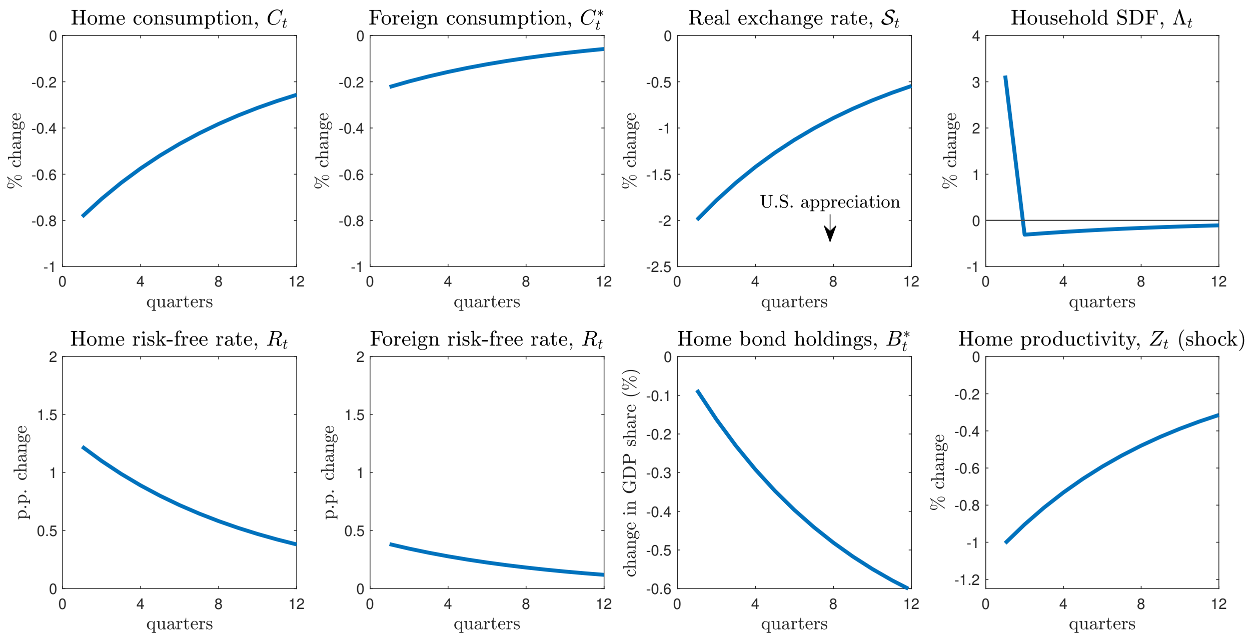
$$C_t + \mathcal{S}_t \left(B_t^* - R_{t-1}^* B_{t-1}^* \right) = \mathcal{T}_t^{-(1-\omega)} Z_t, \tag{81}$$

$$\mathcal{S}_t = \mathcal{T}_t^{2\omega - 1}, \tag{82}$$

where we have substituted out relative prices using the terms of trade $\mathcal{T}_t = P_{F,t}/P_{H,t}$. The eleven conditions (72)-(82) jointly determine the four home variables $\{C_t, C_{H,t}, C_{F,t}, R_t\}$ and their foreign counterparts $\left\{C_t^*, C_{H,t}^*, C_{F,t}^*, R_t^*\right\}$, home's holdings of the international bond B_t^*, and the exchange rate and terms of trade $\{\mathcal{S}_t, \mathcal{T}_t\}$.

We first review in this setting the effects of an unexpected decline in the endowment of the home good Z_t, which will be useful for understanding the impact of uncertainty shocks. Figure 7 shows the effects of a 1 percent decline in Z_t. Given home bias in preferences—whereby the home good has a larger weight in the domestic consumption basket than in the foreign one—domestic consumption C_t suffers a larger decline than C_t^*. Accordingly, the domestic interest rate rises more than the foreign rate. From the UIP condition (74), this interest rate differential in favor of the domestic currency must be associated with a home appreciation (a decline in $\mathcal{S}_t$). The home household's stochastic discount factor, $\Lambda_t \equiv \beta (C_t/C_{t-1})^{-\varrho}$, rises on impact as the fall in consumption raises marginal utility. Thus, fluctuations in the home endowment Z_t generate a negative covariance between the exchange rate $\mathcal{S}_t$ and the SDF Λ_t, implying a *positive* risk premium on the foreign currency, with the foreign currency being weaker in states in which home marginal utility is high

Figure 7: Frictionless model, effects of productivity shock



Note: Responses to a 1 percent decline in home productivity Z_t in the frictionless model without global banking frictions.

and vice versa when it is low.

We now turn to the effects of an increase in uncertainty about future realizations of the home endowment, $\sigma_{z,t}$. In Figure 8, we simulate a shock to the volatility process for $\sigma_{z,t}$ that raises σ_z by nearly 15 percent, as in our original experiment. As made clear by the system (72)-(82), this second moment shock enters the system via the three equilibrium conditions that feature conditional expectations: the two Euler equations (72)-(73) and the UIP condition (74). Thus, the higher future variability of Z_t induces more-variable paths for C_t and C_t^*, which puts downward pressure on both R_t and R_t^*. Because C_t is more responsive to shifts in Z_t than C_t^* is, the decline is larger for R_t. The resulting higher differential favoring the foreign currency puts downward pressure on the home currency.

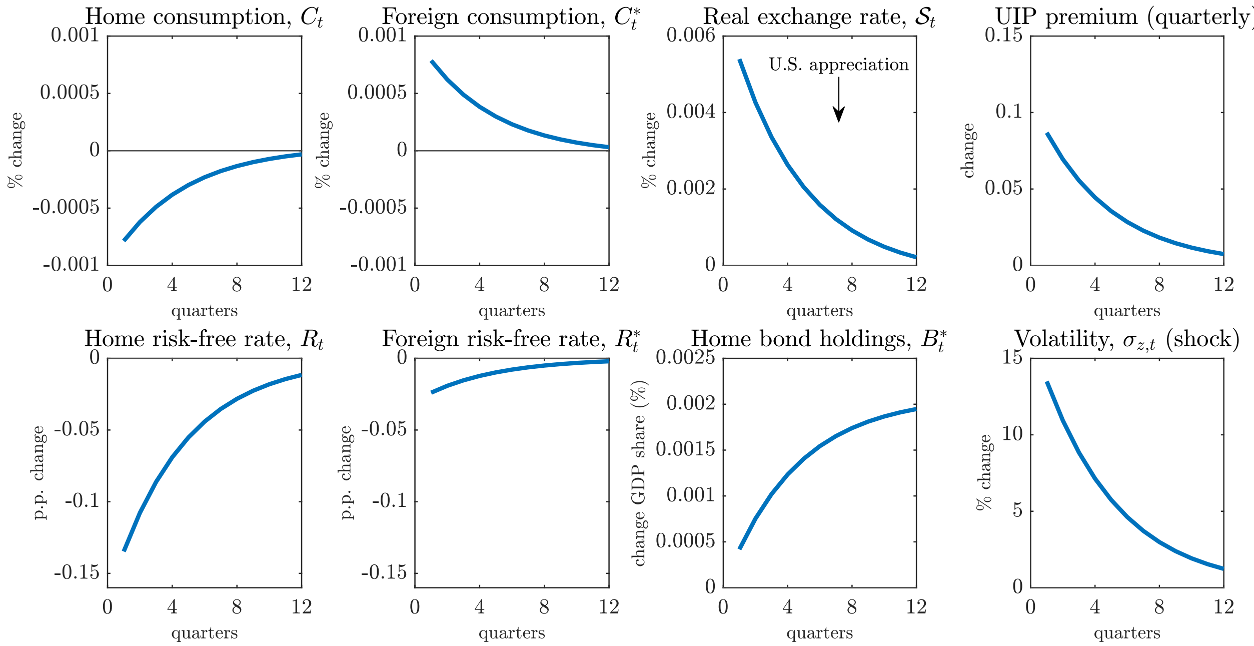
A second force operates through shifts in the risk premium. The covariance between the home household's SDF and the exchange rate becomes more negative (and therefore $\text{Cov}_t(-\Lambda_{t+1}, \mathcal{S}_{t+1})$ rises), which directly translates into a higher UIP premium as shown in the top-right panel—reflecting a higher risk premium on the foreign currency.[14]

[14] Note that equation (74) can be re-written as

$$\mathbb{E}_t\left[\frac{\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t}R_t^*}{R_t}\right] - 1 = \text{Cov}_t\left(-\frac{\Lambda_{t+1}}{\mathbb{E}_t[\Lambda_{t+1}]}, \frac{\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t}R_t^*}{R_t}\right), \tag{83}$$

and therefore the UIP premium, defined as the left-hand-side expression in the equation above, is increasing in $\text{Cov}_t(-\Lambda_{t+1}, \mathcal{S}_{t+1})$. (We show here the quarterly risk premium, as opposed to the annualized one in Figure 3, to avoid the complication in this and associated expressions having to do with forward-cumulating for one year.)

Figure 8: Frictionless model, effects of uncertainty shock



Note: Responses to an uncertainty shock that raises σ_z by nearly 15 percent in the frictionless model without global banking frictions. The shock size matches that used in Figure 3.

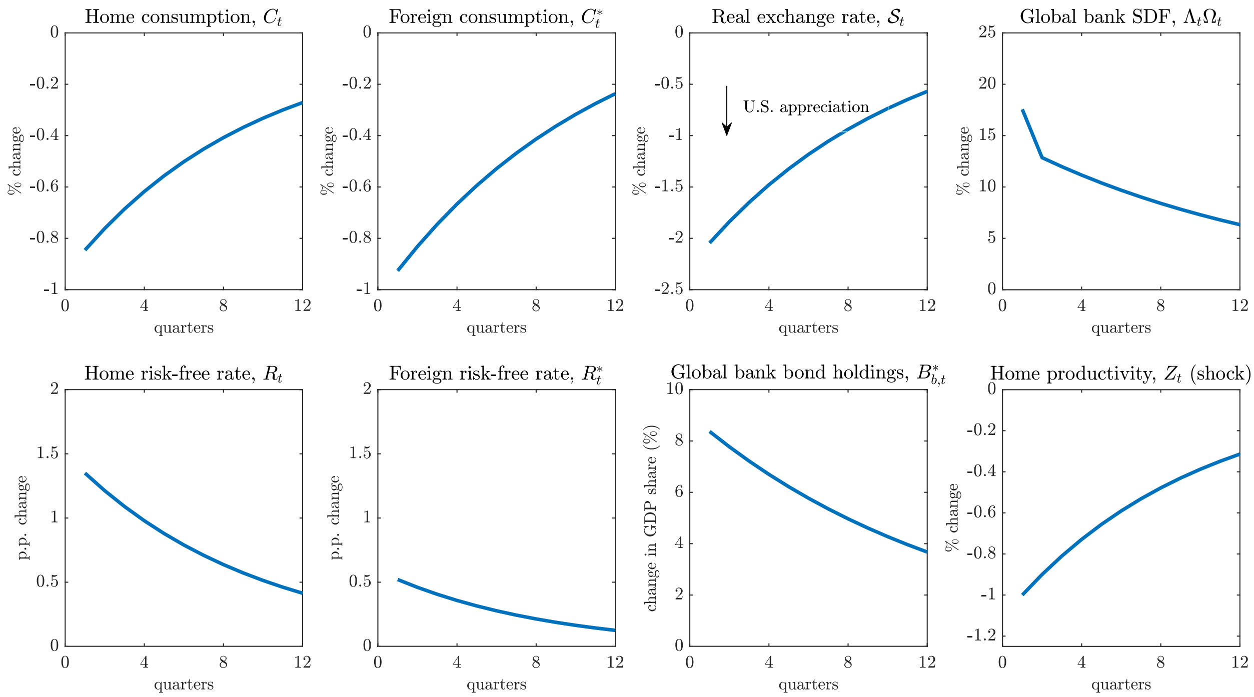
The two forces just described act in opposite directions: the higher risk premium works to appreciate the home exchange rate, whereas the larger decline in the home interest rate relative to the foreign one works to depreciate it. In this benchmark economy, the interest-rate channel dominates, so that on net the home currency depreciates. This depreciation feeds through to quantities by lowering the relative value of the home good, which induces a wealth effect—depressing home consumption and boosting foreign consumption, while at the same time inducing a rise in home net savings B_t^*.

Thus, the effects of an increase in risk in this benchmark economy do not appear consistent with the empirical evidence that higher uncertainty is typically associated with an appreciation of the dollar. Moreover, the exchange rate responses are quantitatively small, reflecting the modest degree of risk aversion in our calibration. In the next subsection, we show how the introduction of global intermediation frictions helps overcome both of these shortcomings.

4.3.2 Uncertainty shocks and exchange rates with constrained global intermediaries

We now return to the full model with global intermediation frictions. A decline in home productivity in that model, shown in Figure 9, has broadly similar effects on the exchange rate as in the frictionless case. The critical difference, however, is that now the relevant stochastic discount factor—the global banker's—increases sharply in response to the lower productivity—by an order

Figure 9: Baseline model with global banking friction, effects of productivity shock



Note: Responses to a 1 percent decline in home productivity Z_t in the baseline model with global banking frictions.

of magnitude more than the increase in the household's SDF in the benchmark model described previously. This occurs because when U.S. productivity is low, global bankers' asset returns are also low; the weak returns trigger financial accelerator effects, which tighten bankers' leverage constraint and make the value of wealth for bankers high. In this way, the presence of constrained global intermediaries works to induce a much larger (absolute value of the) covariance between the exchange rate and global bankers' discount factor—which, from equation (31), is the relevant discount factor for pricing the foreign currency in the model with intermediation frictions.[15,16]

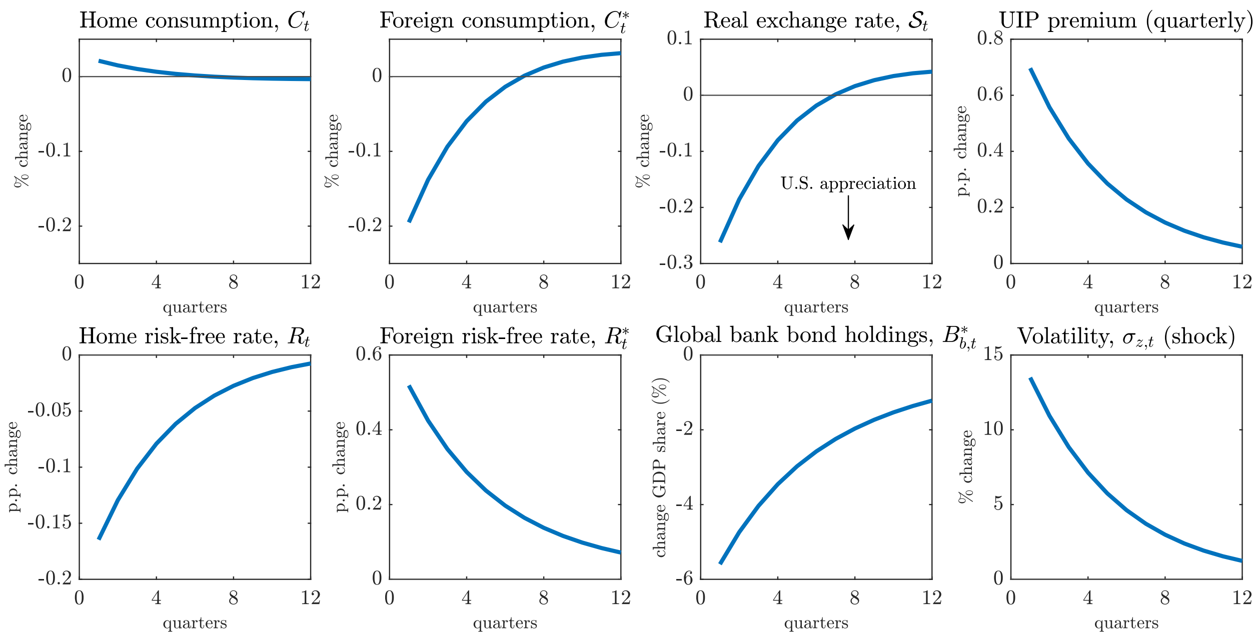
This much larger covariance has material implications for the effects of uncertainty shocks, to which we turn in Figure 10. Note, from that figure, that the rise in the UIP premium is almost eight times as large as in the benchmark economy without intermediation frictions.[17] As a consequence, the associated risk premium effect dominates the interest differential channel (which, as in the

[15] Note from Figure 9 that foreign consumption falls more in our full model than in the previous simple model without intermediation friction. This outcome arises due to the presence of bond management costs by foreign households, and because now the home productivity shock induces an across-the-board decline in asset values, including of foreign capital, which depresses foreign wealth. The presence of bond adjustment costs helps reconcile a lower consumption path than in the frictionless model but a similar path of the foreign risk-free rate (see equation (45)).

[16] The property that a negative first-moment supply shock appreciates the real exchange rate is not crucial to our results. The key channel is that the domestic currency appreciates when intermediary net worth is scarce. In the model of Akinci and Queralto (2023), for example, this is the case when a U.S. monetary tightening happens, or more generally when intermediary net worth deteriorates for other reasons. In both cases an appreciated domestic currency occurs when net worth is scarce and its value therefore high.

[17] By the same token as in footnote 14, note that the UIP premium in the economy with intermediary frictions

Figure 10: Baseline model with global banking friction, effects of uncertainty shock



Note: Responses to an uncertainty shock that raises σ_z by nearly 15 percent in the baseline model with global banking frictions. The shock size matches that used in Figure 3.

frictionless economy, would favor a depreciation of the home currency). As a result, the home real exchange rate now *appreciates* following the increase in uncertainty, consistent with the empirical evidence. Further, the magnitude of the appreciation is substantial, unlike in the frictionless model, in which the exchange rate effects of uncertainty are very small.

Accompanying the stronger dollar is a persistent outflow from foreign bonds by global bankers, as seen in the third panel on the bottom row. The foreign depreciation triggers a decline on foreign consumption, but note that we do not observe a symmetric increase in domestic consumption. This occurs because the uncertainty shock also lowers the value other sources of wealth of the home economy (consisting of holdings of domestic and, to a lesser extent, foreign capital).

These findings are consistent with the often-discussed notion of the dollar as a "safe haven" currency which appreciates in times of higher uncertainty. More specifically, they help rationalize the empirical effects of uncertainty shocks on the dollar that we documented earlier. The key channel is that the marginal pricers of currency risk are global financial intermediaries whose stochastic discount factor is highly responsive to shifts in the returns in U.S. risky capital, thereby magnifying the response of the risk correction term to increases in uncertainty about capital returns. Thus, much as in the simple autarkic economy studied earlier, the fact that global intermediaries

satisfies

$$\mathbb{E}_t\left[\frac{\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t}R_t^*}{R_t}\right]-1=\mathrm{Cov}_t\left(-\frac{\Lambda_{t+1}\Omega_{t+1}}{\mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}]},\frac{\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t}R_t^*}{R_t}\right). \tag{84}$$

are the pricers of foreign currency risks significantly amplifies the effect of an increase in uncertainty on the currency risk premium, in a way that allows the model to generate a dollar appreciation following a rise in domestic risk.

5 Conclusion

How does an increase in uncertainty about U.S. asset returns transmit to global asset prices and exchange rates? Empirically, exogenous increases in U.S. uncertainty raise corporate credit spreads at home and abroad, appreciate the dollar, widen currency risk premia, and lower the U.S. safe rate—the joint signature of the global financial cycle. We have shown that a single, identified second-moment shock reproduces this entire constellation, jointly and with the right sign and magnitude, once it is transmitted through globally active financial intermediaries that face balance-sheet constraints.

We develop a two-country model in which globally active U.S. intermediaries hold domestic and foreign risky capital together with foreign government bonds, but face an endogenous leverage constraint on the size of their balance sheets. The mechanism turns on the marginal value of intermediary net worth. Because leverage constraints make net worth especially valuable precisely when it is scarce, the intermediaries' stochastic discount factor is strongly countercyclical, and the price of risk responds to an uncertainty shock an order of magnitude more than under frictionless asset pricing. The same constrained intermediaries price domestic and foreign risky claims and foreign-currency safe bonds, so the shock passes almost one-for-one to foreign spreads and loads heavily onto the currency risk premium, generating a dollar appreciation even as the U.S. safe rate falls.

The sharpest claim for our mechanism is a negative result. In the frictionless benchmark, the same increase in uncertainty moves two central variables the wrong way: the price of capital rises rather than falls, because precautionary saving lowers the safe rate by more than the risk premium increases, and the dollar depreciates rather than appreciates. Balance-sheet constraints reverse both signs. The constraint is therefore what makes the model consistent with the data. Notably, the dollar's appreciation arises without ascribing any special convenience yield encompassing liquidity or safety services to dollar-denominated assets; it emerges endogenously from the interaction of aggregate uncertainty with intermediary constraints as a complementary mechanism.

References

Adrian, Tobias and Hyun Song Shin, "Procyclical leverage and value-at-risk," *The Review of Financial Studies*, 2014, *27* (2), 373–403.

Akinci, Ozge and Albert Queralto, "Exchange Rate Dynamics and Monetary Spillovers with Imperfect Financial Markets," *The Review of Financial Studies*, 10 2023, *37* (2), 309–355.

Alessandri, Piergiorgio and Haroon Mumtaz, "Financial regimes and uncertainty shocks," *Journal of Monetary Economics*, 2019, *101*, 31–46.

Alfaro, Iván, Nicholas Bloom, and Xiaoji Lin, "The Finance Uncertainty Multiplier," NBER Working Papers 24571, National Bureau of Economic Research, Inc May 2018.

Arellano, Cristina, Yan Bai, and Patrick J Kehoe, "Financial frictions and fluctuations in volatility," *Journal of Political Economy*, 2019, *127* (5), 2049–2103.

Basu, Susanto and Brent Bundick, "Uncertainty Shocks in a Model of Effective Demand," *Econometrica*, 2017, *85* (3), 937–958.

Bloom, Nicholas, "The Impact of Uncertainty Shocks," *Econometrica*, 05 2009, *77* (3), 623–685.

Bodenstein, Martin, Pablo Cuba-Borda, Nils Gornemann, Ignacio Presno, Andrea Prestipino, Albert Queralto, and Andrea Raffo, "Global flight to safety, business cycles, and the dollar," *International Finance Discussion Papers*, 2023, (1381).

di Giovanni, Julian, Sebnem Kalemli-Ozcan, Mehmet Fatih Ulu, and Yusuf Soner Baskaya, "International Spillovers and Local Credit Cycles," *The Review of Economic Studies*, 10 2021, *89* (2), 733–773.

Fernández-Villaverde, Jesús and Pablo A Guerrón-Quintana, "Uncertainty shocks and business cycle research," *Review of economic dynamics*, 2020, *37*, S118–S146.

_ , Pablo Guerrón-Quintana, Juan F Rubio-Ramirez, and Martin Uribe, "Risk matters: The real effects of volatility shocks," *American Economic Review*, 2011, *101* (6), 2530–2561.

Gabaix, Xavier and Matteo Maggiori, "International liquidity and exchange rate dynamics," *The Quarterly Journal of Economics*, 2015, *130* (3), 1369–1420.

Gertler, Mark and Nobuhiro Kiyotaki, "Financial Intermediation and Credit Policy in Business Cycle Analysis," in Benjamin M. Friedman and Michael Woodford, eds., *Handbook of Monetary Economics*, Vol. 3, Elsevier, 2010, chapter 11, pp. 547–599.

_ and _ , "Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy," *American Economic Review*, 2015, *105* (7), 2011–43.

— **and Peter Karadi**, "A model of unconventional monetary policy," *Journal of Monetary Economics*, 2011, *58* (1), 17 – 34.

— **, Nobuhiro Kiyotaki, and Albert Queralto**, "Financial crises, bank risk exposure and government financial policy," *Journal of Monetary Economics*, 2012, *59, Supplement*, S17 – S34.

He, Zhiguo and Arvind Krishnamurthy, "Intermediary asset pricing," *American Economic Review*, 2013, *103* (2), 732–70.

Ilzetzki, Ethan, Carmen M Reinhart, and Kenneth S Rogoff, "Exchange Arrangements Entering the 21st Century: Which Anchor Will Hold?," Working Paper 23134, National Bureau of Economic Research February 2017.

Itskhoki, Oleg and Dmitry Mukhin, "Exchange Rate Disconnect in General Equilibrium," *Journal of Political Economy*, 2021, *129* (8), 2183–2232.

Jiang, Zhengyang, Arvind Krishnamurthy, and Hanno Lustig, "Foreign Safe Asset Demand and the Dollar Exchange Rate," *The Journal of Finance*, 2021, *76* (3), 1049–1089.

Kalemli-Ozcan, Sebnem, "U.S. Monetary Policy and International Risk Spillovers," *Proceedings - Economic Policy Symposium - Jackson Hole*, 2019.

— **and Liliana Varela**, "Five Facts about the UIP Premium," Working Paper 28923, National Bureau of Economic Research June 2021.

Kekre, Rohan and Moritz Lenel, "The Flight to Safety and International Risk Sharing," *American Economic Review*, June 2024, *114* (6), 1650–91.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen, "The aggregate demand for treasury debt," *Journal of Political Economy*, 2012, *120* (2), 233–267.

Lucas, Robert Jr., "Asset prices in an exchange economy," *Econometrica: Journal of the Econometric Society*, 1978, pp. 1429–1445.

Mehra, Rajnish and Edward C Prescott, "The equity premium: A puzzle," *Journal of Monetary Economics*, 1985, *15* (2), 145–161.

Miranda-Agrippino, Silvia and Hélene Rey, "U.S. Monetary Policy and the Global Financial Cycle," *The Review of Economic Studies*, 2020.

— **and** — , "The Global Financial Cycle," in "Handbook of International Economics" Handbook of International Economics 2021.

Morelli, Juan M., Pablo Ottonello, and Diego J. Perez, "Global Banks and Systemic Debt Crises," *Econometrica*, 2022, *90* (2), 749–798.

Rey, Hélène, “Dilemma not trilemma: the global cycle and monetary policy independence,” *Proceedings - Economic Policy Symposium - Jackson Hole*, 2013.

Òscar Jordà, “Estimation and Inference of Impulse Responses by Local Projections,” *American Economic Review*, March 2005, *95* (1), 161–182.

Online Appendix

A Sample Description and Data Sources

Country sample for panel regressions: We use countries listed in Table A.1, and drop country-quarters with peg ER regimes (IRR classifications 1 and 6).

Table A.1: Country Sample

Argentina	Euro Area	Malaysia	Russia	United Kingdom
Brazil	Indonesia	Mexico	South Africa	
Canada	Israel	Peru	Thailand	
Colombia	Korea	Philippines	Turkey	

Note: Black = advanced economies (4); Red = emerging markets (13).

Note: We follow the IMF 2000 World Economic Outlook country groups classification. Because we measure U.S. uncertainty spillovers, we drop the U.S. Red text indicates a country is an emerging market.

Table A.2: Data sources and description

Variable	Description	Source
UIP	12-month UIP deviations	IFS, Bloomberg, Consensus Economics
Real Exchange Rate	Broad dollar index	Federal Reserve Board
Corporate Spreads	Dollar denominated corp. bond spreads	ICE indices and J.P. Morgan
U.S. Gov. Bond rate	Yields on 5-year Gov. Bonds	Federal Reserve Board

B Empirical Evidence: Additional Results

Figure B.11: **VIX**

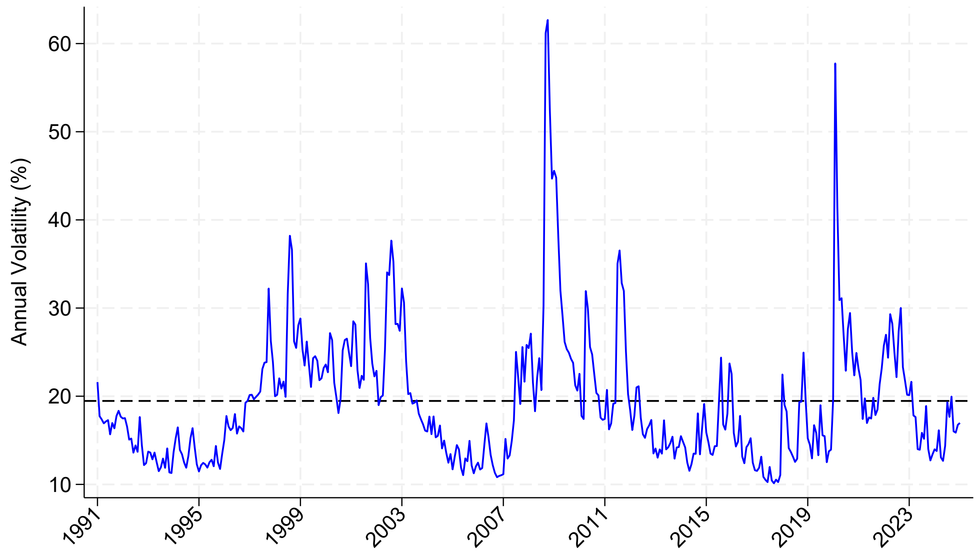
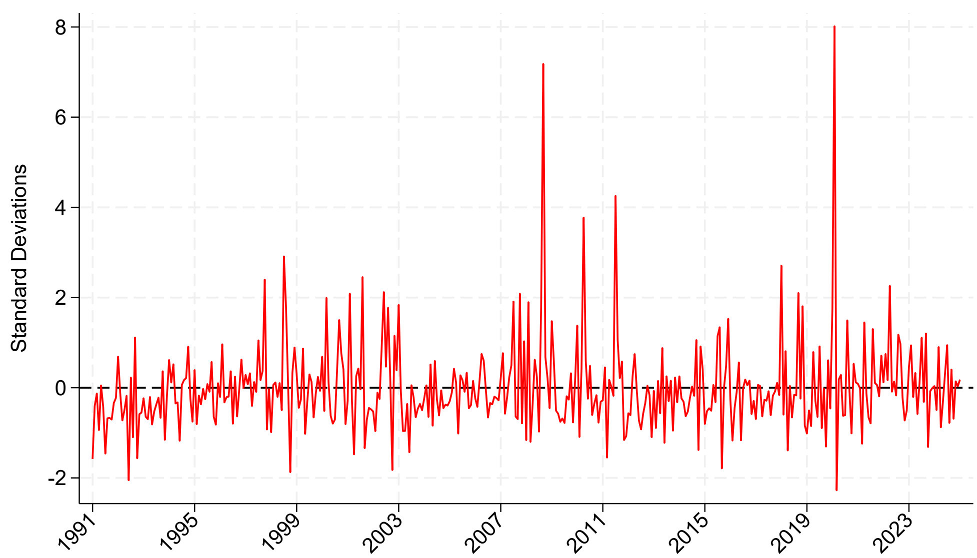


Figure B.12: **Identified Uncertainty Shocks**



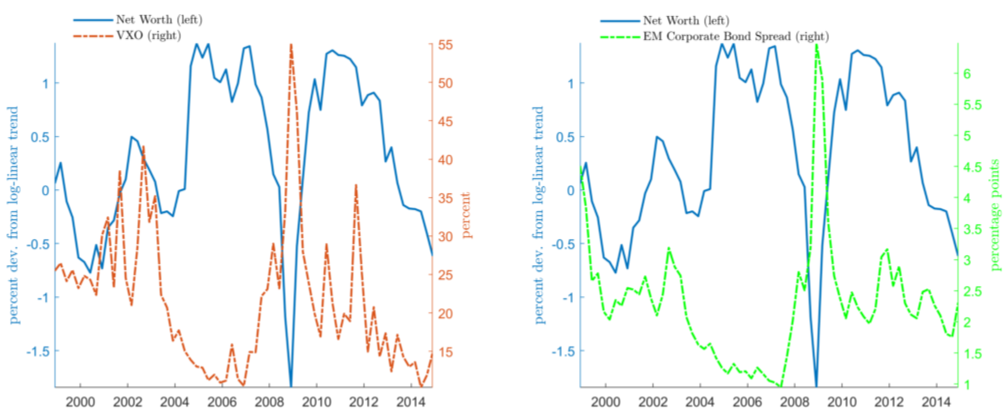
Note: The shocks are calculated as the residuals of a regression of the VIX on contemporaneous and lagged values of 12-month percent change in U.S. industrial production and the level federal funds rate, as well as lagged values of VIX itself. We used monthly data from 1990 to 2024, and included 12 lags in the estimation.

C Uncertainty Shocks, Global Banks' Net Worth, and EM Corporate Spreads

The price of EM corporate bonds held by global investors is highly correlated with uncertainty (proxied by the VXO). Moreover, fluctuations in uncertainty appear to be related to global financial intermediaries' equity positions. These observations are illustrated in Figure C.1, which shows the evolution of the VXO, along with U.S. banks' net worth position and EM corporate bond spreads, over the 1998-2014 period.

These observations suggest that uncertainty shocks might potentially transmit to EM risky asset prices through their impact on global banks' equity position. In this section we attempt to provide some motivational evidence using macro-level regressions for the presence of such channel. More specifically, we begin with the following regression:

Figure C.1: EM Corporate Spread, VXO, and U.S. Banks' Net Worth.



Note: Spreads (expressed in percentage points) is the JP Morgan Corporate Bond Index for the EM aggregate. The U.S. banks' net worth is defined as the difference between the real value of assets and liabilities reported by U.S. chartered depository institutions obtained from the Federal Reserve Board, Flow of Funds, and displayed as a percent change from a loglinear trend (computed as in Morelli et al. (2022)). VXO is the Chicago Board Options Exchange's CBOE Volatility Index, also expressed in percent.

$$\Delta Spread_{c,t} = \eta_c + \alpha NW_{t-1}\Delta VXO_t + \beta \Delta VXO_t + \delta NW_{t-1} + \epsilon_t \qquad \text{C.1}$$

where the quarterly changes in EM corporate bond spreads ($\Delta Spread_{c,t}$) are regressed on the interaction term between the change in a measure of global uncertainty and the lagged value of U.S. banks' net worth ($NW_{t-1}\Delta VXO_t$). In the regressions we control for the change in VXO (ΔVXO_t) and the (lagged) values of the net worth positions of the U.S. banks (NW_{t-1}), as well as the Global Financial Crisis (where the dummy for the latter takes a value of 1 for the 2008Q3-2009Q4 period and zero otherwise). Note that we use data from 20 EMs on the risk premia that the corporates in these countries have pay in the international markets to borrow from global banks, and run regressions using the country fixed effects (η_c).

Table C.1: EM Corporate Spreads, Uncertainty and U.S. Banks' Net Worth

	(1)	(2)	(3)	(4)
	$\Delta Spread_{c,t}$	$\Delta Spread_{c,t}$	$\Delta Spread_{c,t}$	$\Delta Spread_{c,t}$
$NW_{t-1}\Delta VXO_t$	0.0239***	-0.0488***	-0.0500***	-0.0503***
	(4.43)	(-5.99)	(-6.16)	(-6.19)
ΔVXO_t		0.0899***	0.0913***	0.0917***
		(11.20)	(11.43)	(11.45)
NW_{t-1}			-0.166**	-0.195**
			(-2.89)	(-2.92)
GFC Dummy				-0.129
				(-0.86)
Country Fixed Effects	yes	yes	yes	yes
Observations	651	651	651	651

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t statistics in parentheses.

Note: Spread represents the JP Morgan Corporate EM Bond Index for 20 EMs (denoted by c) over the Q4 1998 to Q4 2014 period (denoted by t). EMs include Argentina, Brazil, Chile, China, Colombia, Hong Kong, India, Indonesia, Israel, Korea, Mexico, Malaysia, Philippines, Russia, Saudi Arabia, Singapore, South Africa, Taiwan, Thailand, Turkey. The U.S. banks' net worth (NW) is defined as the difference between the real value of assets and liabilities reported by U.S. chartered depository institutions obtained from the Federal Reserve Board, Flow of Funds (computed as in Morelli et al. (2022)). VXO is the Chicago Board Options Exchange's CBOE Volatility Index. The global financial crisis (GFC) is defined between Q3 2008 and Q4 2009. The results are robust to including EM local currency bonds.

Table C.1 presents the results of regression C.1. The estimated coefficient for the effect of VXO on the spread is positive and significant, implying that higher uncertainty is associated with higher corporate bond spreads in EMs. More importantly, once we control for changes in VXO, we find that the interaction term that we are interested in becomes negative and significant: if the net worth positions of global banks are low in the previous period (implying that the banks are more likely to be constrained), EM corporate spreads increase by more for an increase in the VXO of a given size. Or conversely, if global banks are well-capitalized (NW is high in the previous period, and thus financial constraints are more relaxed), EM corporate bond spreads move less for a given change in VXO in the current period. So, we take this finding as a suggestive evidence that global banks' net worth plays an important role in transmitting uncertainty shocks to the price of EM corporate bonds.

D Complete Set of Equilibrium Conditions

The model's full set of equilibrium conditions is listed below.

Global banks:

$$\nu_t = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}]R_t \quad \text{D.1}$$

$$\mu_t = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}(R_{k,t+1} - R_t)] \quad \text{D.2}$$

$$\mu_t^* = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}(R_{k,t+1}^* - R_t)] \quad \text{D.3}$$

$$\mu_{B,t}^* = \mathbb{E}_t[\Lambda_{t+1}\Omega_{t+1}(\frac{\mathcal{S}_{t+1}}{\mathcal{S}_t}R_t^* - R_t)] \quad \text{D.4}$$

$$\mu_t^* = \mu_t \quad \text{D.5}$$

$$\mu_{B,t}^* = 0 \quad \text{D.6}$$

$$\phi_t + \phi_t^* = \frac{\nu_t}{\theta - \mu_t} \quad \text{D.7}$$

$$\Omega_{t+1} = 1 - \sigma + \sigma\left(\phi_{t+1}\mu_{t+1} + \phi_{t+1}^*\mu_{t+1}^* + \nu_{t+1}\right) \quad \text{D.8}$$

$$Q_t K_{B,t} = \phi_t N_t \quad \text{D.9}$$

$$Q_t^* K_{B,t}^* = \phi_t^* N_t \quad \text{D.10}$$

$$\begin{aligned} N_t = \sigma\Big[&(R_{k,t} - R_{t-1})Q_{t-1}K_{B,t-1} + (R_{k,t}^* - R_{t-1})Q_{t-1}^*K_{B,t-1}^* + \left(\frac{\mathcal{S}_t}{\mathcal{S}_{t-1}}R_{t-1}^* - R_{t-1}\right)\mathcal{S}_{t-1}B_{B,t-1}^* \\ &+ R_{t-1}N_{t-1}\Big] + (1-\sigma)\xi\left[Q_{t-1}K_{B,t-1} + Q_{t-1}^*K_{B,t-1}^* + \mathcal{S}_{t-1}B_{B,t-1}^*\right] \end{aligned} \quad \text{D.11}$$

Home households:

$$C_{H,t} = \omega\left(\frac{P_{H,t}}{P_t}\right)^{-1}C_t \quad \text{D.12}$$

$$C_{F,t} = (1-\omega)\left(\frac{P_{F,t}}{P_t}\right)^{-1}C_t \quad \text{D.13}$$

$$1 = \beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\varrho}\right]R_t \quad \text{D.14}$$

$$\alpha\frac{K_{H,t}^{\eta}}{C_t^{-\varrho}} + Q_t = \beta\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\varrho}(\frac{P_{H,t+1}}{P_{t+1}}Z_{t+1} + Q_{t+1})\right] \quad \text{D.15}$$

Foreign households:

$$C_{H,t}^* = (1-\omega)\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-1}C_t^* \quad \text{D.16}$$

$$C_{F,t}^* = \omega\left(\frac{P_{F,t}^*}{P_t^*}\right)^{-1}C_t^* \quad \text{D.17}$$

$$\alpha_b^*\frac{B_{H,t}^*}{(C_t^*)^{-\varrho}} + 1 = \beta\mathbb{E}_t\left[\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\varrho}\right]R_t^* \quad \text{D.18}$$

$$\alpha^* \frac{(K^*_{H,t})^\eta}{(C^*_t)^{-\varrho}} + \frac{Q^*_t}{\mathcal{S}_t} = \beta \mathbb{E}_t \left[\left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\varrho} \left(\frac{P^*_{F,t+1}}{P^*_{t+1}} Z^*_{t+1} + \frac{Q^*_{t+1}}{\mathcal{S}_{t+1}} \right) \right] \tag{D.19}$$

Real exchange rate, market clearing, and balance of payments:

$$\mathcal{S}_t = \mathcal{T}_t^{2\omega-1} \tag{D.20}$$

$$C_{H,t} + C^*_{H,t} = Z_t \tag{D.21}$$

$$C_{F,t} + C^*_{F,t} = Z^*_t \tag{D.22}$$

$$K_{H,t} + K_{B,t} = 1 \tag{D.23}$$

$$K^*_{H,t} + K^*_{B,t} = 1 \tag{D.24}$$

$$B^*_{H,t} + B^*_{B,t} = 0 \tag{D.25}$$

$$C_t + Q^*_t(K^*_{B,t} - K^*_{B,t-1}) + \mathcal{S}_t(B^*_{B,t} - R^*_{t-1}B^*_{B,t-1}) = \frac{P_{H,t}}{P_t} Z_t + \frac{P_{F,t}}{P_t} Z^*_t K^*_{B,t-1} \tag{D.26}$$

Given the definitions

$$R_{k,t+1} \equiv \frac{\frac{P_{H,t+1}}{P_{t+1}} Z_{t+1} + Q_{t+1}}{Q_t},$$
$$R^*_{k,t+1} \equiv \frac{\frac{P_{F,t+1}}{P_{t+1}} Z^*_{t+1} + Q^*_{t+1}}{Q^*_t},$$
$$\Lambda_{t+1} \equiv \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\varrho},$$

the law of one price ($P_{H,t} = P^*_{H,t}$, $P_{F,t} = P^*_{F,t}$), the terms of trade definition $\mathcal{T}_t \equiv P_{F,t}/P_{H,t}$, and the expressions $P_t = P^\omega_{H,t} P^{1-\omega}_{F,t}$, $P^*_t = (P^*_{F,t})^\omega (P^*_{H,t})^{1-\omega}$, which together allow re-writing all relative goods prices solely as functions of the terms of trade, the system of equations D.1-D.26 can be used to solve for the variables relating to global banks ($N_t, \Omega_t, \nu_t, \mu_t, \mu^*_t, \mu^*_{B,t}$, ϕ_t, ϕ^*_t, $K_{B,t}, K^*_{B,t}$, $B^*_{B,t}, Q_t, Q^*_t$), home households ($C_{F,t}, C_{H,t}, C_t, K_{H,t}, R_t$), foreign households ($C^*_{F,t}, C^*_{H,t}, C^*_t$, $K^*_{H,t}, R^*_t$, $B^*_{H,t}$), and international prices ($\mathcal{T}_t, \mathcal{S}_t$).

E First- v. Second-Moment Shocks

Figure E.1 contrasts the effects of an uncertainty shock in our baseline experiment (the blue solid lines) to those of a first-moment shock. Specifically, we simulate a decrease in asset returns Z_t sized to generate the same decline in the domestic asset price Q_t as in the uncertainty shock case. Although the first-moment shock raises credit spreads and appreciates the dollar, it also increases the U.S. safe interest rate—in contrast to an uncertainty shock, which lowers it, consistent with the data. Moreover, the first-moment shock produces only modest movements expected equity-return volatility (the VIX), indicating that it mainly operates through changes in expected returns rather than through heightened uncertainty about future returns.

Figure E.1: Effects of first- v. second-moment shocks