

# GLOBAL BANKS AND SYSTEMIC DEBT CRISES\*

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ABSTRACT. We study the role of financial intermediaries in the global market for risky external debt. We first provide empirical evidence measuring the effect of global banks' net worth on bond prices of emerging-market economies. We show that, around Lehman Brothers' collapse, within emerging-market bonds with similar risk, those held by more distressed global banks experienced larger price contractions. We then construct a model of global banks' lending to emerging economies and quantify their role using our empirical estimates and other key data. In the model, banks' net worths affect bond prices by the combination of a form of market segmentation and banks' financial frictions. We show that these banks' exposure to emerging economies significantly determines their role in propagating shocks. With the current observed exposure, global banks play an important role in transmitting shocks originating in developed economies, accounting for the bulk of the variation of spreads in emerging economies during the recent global financial crisis. Global banks help explain key patterns of debt prices observed in the data, and the evolution of their exposure over recent decades can explain the changing nature of systemic debt crises in emerging economies.

Keywords: Financial intermediaries, debt crises, external debt, world economy

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## 1. INTRODUCTION

Debt crises in emerging-market economies are global in nature. They affect multiple economies in a synchronized fashion and compromise the stability of global financial intermediaries. Salient examples of these events include the Latin American debt crises of the 1980s, linked to major U.S. banks; the Russian/East Asian crises in the 1990s, linked to the collapse of the LTCM fund; and the recent global financial crisis, linked to U.S. and European banks, which affected most emerging economies. Based on the recurrent nature of these episodes, a commonly held view in policy circles is that “global banks” (i.e., financial intermediaries operating in the world economy) play an important role in shaping systemic debt crises. However, most academic literature analyses debt crises abstracting from any explicit role of global financial intermediaries.

In this paper, we reassess this long-held view in policy circles by studying the role of global banks in systemic debt crises. We do so by providing new empirical evidence complemented with a framework to study the global nature of these phenomena. Our empirical analysis studies whether well-identified shocks to global banks’ net worth affect bond prices in emerging economies. For this, we exploit the variation in emerging-market bond prices with comparable risk during a short window around the Lehman episode, and document larger price drops in bonds held by more-affected global banks. We then construct a model of global banks’ lending to emerging economies, and quantify their role using our empirical estimates as well as other key data. In the model, the reason banks’ net worths affect bond prices is the combination of a form of market segmentation, which prevents the equalization of expected returns across asset classes, and banks’ financial frictions, which link the banks’ abilities to supply funds to their net worths. We find that these banks’ exposure to emerging economies is the key to determine their role in propagating shocks. With the current observed relatively low exposure, global banks play a major role in transmitting shocks originating in developed economies. In fact, we show that the bulk of the variation of spreads in emerging economies during the recent global financial crisis can be explained by negative shocks to risky assets in developed economies that affected global banks’ net worths. In addition, we show that global banks help explain key patterns of debt prices, including the large comovement observed within emerging economies and with other risky securities, and that the evolution of banks’ exposure over recent decades can explain the changing nature of systemic debt crises in emerging economies.

Our empirical analysis seeks to measure the effect of global banks on emerging-market bond prices. The main empirical challenge for this task is that changes in global banks’ net worths

are linked to other factors driving emerging-market default risk. The key idea of our empirical strategy is that bonds of a given country and sector have similar default risk, but are held by different financial intermediaries. We can then identify the effect of global banks' net worth on emerging-market bond prices by relating the average contraction in the net worth of the financial intermediaries holding a particular bond in a narrow window around the Lehman episode to its subsequent price drop. To measure the average contraction in the net worth of the financial intermediaries holding a particular bond, we collect data on the holdings of each financial intermediary of each individual bond, as well as data on the stock price drop of each publicly traded financial intermediary. We document that bonds held by more severely affected banks during this episode experienced more severe price drops in the two subsequent months. The estimated elasticity is quantitatively large: Bonds whose holders suffer a contraction in net worth one standard deviation higher than the mean experienced a price contraction twice as large as that of the average bond.

We then construct a model of global banks' lending to emerging economies, and use the model together with our empirical estimates to analyze their role in systemic debt crises. We model the world economy as composed by a set of heterogeneous emerging economies facing systemic and idiosyncratic income shocks, which borrow from developed economies using risky debt. Global banks intermediate in this international lending process, but face financing frictions linking investments in risky securities to their net worth. The model, while rich enough to be quantified to explain the data, hinges on key forces that can be characterized in a stylized way. Required returns on emerging-economy debt are determined endogenously and include an intermediation premium and a default-risk component. The intermediation premium is determined to equilibrate aggregate supply and demand of funds for risky assets. This way, shocks that contract the supply of funds, like lower realized returns on global banks' investments, increase the intermediation premium. The default premium is determined by borrowers' incentives to default.

One of our model's main takeaways is that the type of role played by global banks crucially depends on their exposure to emerging-market risky debt. On the one hand, when their exposure is high, global banks play a key role amplifying shocks originating in emerging economies, through a feedback effect between the supply of funds and emerging economies' default rates. On the other hand, when the exposure is low, global banks play a key role in transmitting shocks originating in other risky asset classes.

To quantitatively assess this role, we measure this exposure and inform the model with the estimated elasticity from our empirical analysis. Our empirical estimates are informative of global banks' marginal costs of external finance. When these marginal costs are high, shocks that affect global banks' net worth lead to large effects on emerging-market bond prices, as banks require larger returns to be willing to raise external finance and purchase risky securities. We calibrate global banks' marginal cost of finance in our model so that the elasticity from global banks' net worth to bond prices in the model matches that estimated in the data. In addition, our quantitative model of the global debt market is parametrized to match central elements of the data using a numerical solution that combines global methods—to deal with global risk—with an approximation of the distribution of assets in the world economy.

We find that, with the current observed exposure (around ten percent of risky assets) and estimated costs of external finance, global banks mostly play a role in transmitting shocks originating in developed economies. We illustrate the relevance of their role by showing that the bulk of the variation of emerging-market spreads during the global financial crises can be explained by negative shocks in developed economies that affected the net worth of global banks. In addition, global banks can help explain why bond spreads in the data are highly correlated within emerging economies, and also highly correlated with the returns of other risky securities in developed economies, such as U.S. corporate bonds. In our model, an important part of the fluctuations in debt prices are driven by changes in banks' net worth and the aggregate supply of funds, leading to large comovements similar to those observed in the data.

Finally, our global-bank model sheds light on the history of systemic debt crises in emerging economies. For instance, a common narrative of why the Latin American debt crisis of the 1980s was so pronounced, is that U.S. banks had a very large exposure to these economies, and when their default rates increased banks had to significantly contract credit, further affecting the ability of Latin American economies to repay. Our model captures exactly this mechanism, and shows that the dynamics observed in this crisis are what would have been predicted in our quantitative model when global banks' exposure is large. Our model can also explain why, over recent decades, when financial lenders were more diversified in their portfolios, most of the swings in emerging-market debt prices were linked to changes in realized returns of risky securities in developed economies, as illustrated for instance by the 2008 Lehman episode.

### *Related literature*

Our paper contributes to several strands of the literature. First, to the literature that studies external debt crises and sovereign default. This literature has shown how the dynamics

of external borrowing in emerging economies can be linked to frictions in international credit markets (see, for example, [Mendoza, 2002, 2010](#); [Bianchi, 2011](#)) and default risk (see, for example, [Arellano, 2008](#); [Aguiar and Gopinath, 2006](#)). Motivated by the high synchronization of debt crises, a recent part of this literature has analyzed the role of lenders in the debt market (see, for example, [Aguiar et al., 2016](#); [Tourre, 2017](#); [Arellano et al., 2017](#); [Bai et al., 2018](#)). Our paper contributes to this literature by analyzing debt crises from a global perspective and focusing on the role of financial intermediaries in this market.

Second, our paper contributes to the literature on the history of debt crises (see, for example, [Calvo and Mendoza, 1996](#); [Reinhart and Rogoff, 2009](#); [Kaminsky and Reinhart, 1999](#); [Sachs, 1989](#)). A relevant takeaway from this literature is that financial intermediaries play a key role in emerging economies' debt crises. We contribute to this literature by constructing a model of the world economy with global financial intermediaries that allows us to further understand the channels through which global banks can play an important role in these crises.

Third, our paper is related to the literature on international asset prices and the global financial cycle. This literature has documented a large comovement in debt prices across emerging economies (see, for example, [Longstaff et al., 2011](#); [Borri and Verdelhan, 2011](#)), and a strong link between international capital flows and lending in emerging economies (see, for example, [Gourinchas and Rey, 2007](#); [Devereux and Yetman, 2010](#); [Rey, 2015](#); [Baskaya et al., 2017](#); [Avdjiev et al., 2018](#)). Our paper shows that global banks can play a key role in these patterns. In this sense, our paper is also related to [Gabaix and Maggiori \(2015\)](#), who study the role of global financial intermediaries in asset markets.

Finally, our paper contributes to the literature on the role of financial intermediaries in the macroeconomy (see, for example, [Gertler and Karadi, 2011](#); [Gertler and Kiyotaki, 2010](#)). The closest contributions are [Gennaioli et al. \(2014\)](#), [Bocola \(2016\)](#), [Brunnermeier et al. \(2016\)](#), and [Perez \(2018\)](#), which analyze the role of banks as lenders to risky governments. We contribute to this literature by stressing that the same frictions that help understand financial frictions domestically are relevant in the synchronization of global debt crises and debt prices.

The rest of the paper is organized as follows. Section 2 presents the empirical evidence. Section 3 lays out the model. Section 4 discusses the channels through which global banks amplify and transmit shocks in the risky debt market. Section 5 presents the calibration. We perform the main quantitative exercises in Section 6, and conclude in Section 7.

## 2. EMPIRICAL EVIDENCE

In this section, we provide empirical evidence of the effect of changes in global banks' net worth on emerging-market (EM) debt prices. The estimates obtained constitute new evidence for the role of global banks in EM debt prices, and are also helpful to discipline and quantify the aggregate effects of global banks in the debt market in the next sections.

### 2.1. Identification

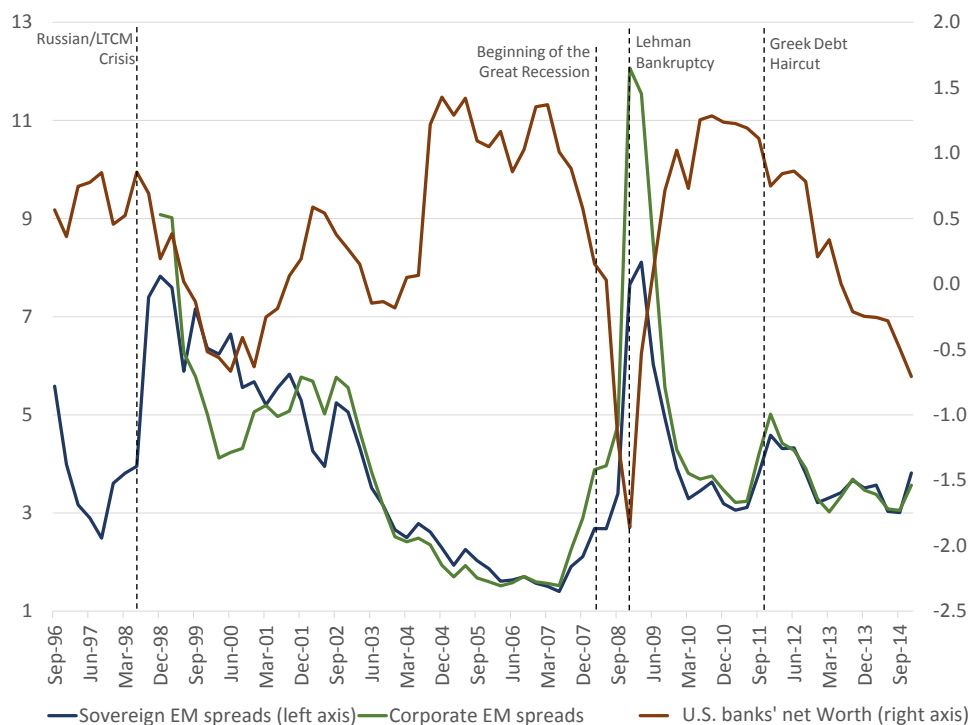
Figure 1 shows the comovement between EM sovereign and corporate bond spreads and U.S. global banks' net worth over recent decades, characterized by a strong negative correlation of roughly  $-0.55$ . Spikes in bond spreads—such at the Russian and East Asian crises of the late 1990s or around the Lehman Brothers bankruptcy in 2008—tend to mark periods of declines in U.S. banks' net worth. Our goal is to measure the effect of global banks' net worth on bond prices. The main empirical challenge is that changes in global banks' net worth are correlated with drivers of EM default risk. In addition, changes in net worth are themselves affected by EM returns.

Our empirical strategy to estimate global banks' effect on EM bond prices exploits bond-level variation in prices in a narrow window around the Lehman episode. The key idea of this identification strategy is to compare the variation in bond prices with similar default risk but different holders. For instance, all foreign-currency sovereign bonds issued by Mexico in foreign markets have the same default risk (e.g., due to cross-default clauses), but are held by different global banks. Moreover, in a narrow window around the Lehman episode (that we define from ten days before to three days after September 15, 2008), global banks experienced differential changes in their net worth primarily driven by developed-market (DM) factors. We can, therefore, exploit this episode to identify the effect of global banks' net worth on bond prices by relating the within-country-sector variation in bond prices to a measure of their holders' net-worth change.

### 2.2. Data

*EM bond prices.* We collect data on daily prices for sovereign and corporate bonds issued by countries that are part of the EMBI. The set of twenty-five countries included in our sample is detailed in Appendix B.1. We restrict attention to bonds issued before 2008, maturing after 2010, and issued in foreign markets and in foreign currency, which are arguably more comparable in terms of their default risk. The data sources are Bloomberg and Datastream,

FIGURE 1. Emerging-Market Bond Spreads and U.S. Banks' Net Worth



*Notes:* This figure shows emerging-market sovereign and corporate bond spreads and U.S. banks' net worth. Bond spreads are expressed in percent and are computed as the average spreads across countries included in JP Morgan's Emerging Markets Bond Index (EMBI; for sovereign spreads) and Corporate Emerging Markets Bond Index (CEMBI; for corporate spreads). Data source: Bloomberg. The net worth of U.S. global banks refers to the difference between the real value of assets and liabilities reported by U.S. chartered depository institutions. Data expressed as percentages relative to a log-linear trend. Data source: Federal Reserve Board, Flow of Funds.

from which we obtain a sample of over 400 EM bonds. Appendix Table A1 report descriptive statistics of our sample of bonds per country.

Our variables of interest are the change in bond prices and yield to maturities following the Lehman episode. Their evolution are summarized in Table 1 and Figure A1. The first column of Table 1 reports statistics of the variation of EM bond prices in the narrow window around the Lehman episode, showing an average EM bond price contraction of 3% and a standard deviation of 4%. The second column of Table 1 reports statistics of the resulting change in yield to maturities in this window, which exhibits an average increase of 57 basis points and

a standard deviation of 37 basis points.<sup>1</sup> Figure A1, shows the average and standard deviation of cumulative changes in daily log price and yield to maturities up to two months after the Lehman episode. On average, EM bond prices exhibit a maximum contraction forty days after the Lehman episode of around 7%, which resulted in an average increase in yield to maturities of 4 percentage points.

*Shares of EM bond holdings by global banks.* For each bond in our sample, we collect data on holdings by financial institutions prior to the Lehman episode from Bloomberg. These data contain, for each individual bond (at the CUSIP level), the share held by each reporting financial institution, including banks, hedge funds, holding companies, insurance companies, investment advisors, pension funds, private equity, venture capital, and other financial institutions. Within these holders, we focus on financial institutions that are publicly traded in DM economies, which is our empirical measure of “global banks.” Appendix Table A2 details the fifty global financial institutions included in the empirical analysis meeting this selection criteria, and Table A3 reports descriptive statistics for the twenty financial institutions with largest EM bond holdings in our sample. As shown in the second column of Table 1, on average, global banks included in our sample held 37% of reported bond holdings in 2008.q2, prior to the Lehman episode.

*Change in global banks’ net worth per bond.* We construct a measure of the change in bond holders’ average net worth around the Lehman episode, defined as  $\Delta n_i = \sum_{j=1}^J \theta_{ij} \Delta n_j$ , where  $\theta_{ij}$  is the share held by bank  $j$  of bond  $i$  at 2008.q2 (using the shares described above),  $\Delta n_j$  is bank  $j$ ’s change in log stock price around Lehman’s bankruptcy (ten days before and three days after September 15, 2008), and  $J$  denotes the set of banks with available data. We measure  $\Delta n_j$  as the change in its log stock price, with data also from Bloomberg and Datastream.

Table 1 provides summary statistics of the change in global banks’ net worth at the bank and bond level. The third column of Table 1 reports descriptive statistics at the bank level, showing an average contraction in bank net worth in the narrow window around the Lehman episode of 19%. The contraction of EM bond prices (shown in the first column of Table 1) is relatively small compared to global banks’ net worth contraction, supporting the view that most of the change in global banks’ net worth in this episode was primarily driven by DM factors.<sup>2</sup> The last column shows that, after weighting global banks by their holdings prior to the Lehman

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<sup>1</sup>We estimate the yield to maturities of bond prices using information on coupons and maturities of each individual bond.

<sup>2</sup>In addition, as we show in Section 5, the exposure of global banks to EMs is around 10% of their risky assets, so the average contraction of 3% in EM bond prices during the narrow window considered should only have modest effects relative to the 19% average contraction in global banks’ net worth.



TABLE 1. Global Banks' Net Worth and Emerging-Market Bond Prices during the Lehman Episode: Summary Statistics

	$\Delta q_i$	$\Delta ytm_i$	$\sum_j \theta_{ij}$	$\Delta n_j$	$\Delta n_i$
	Bond price	Bond yield	Bank coverage	Bank level	Bond level
Mean	-3%	57bps	37%	-19%	-12%
Median	-2%	37bps	34%	-3%	-8%
Std Deviation	4%	82bps	24%	85%	22%
5th percentile	-12%	-20bps	5%	-61%	-33%
95th percentile	1%	251bps	88%	20%	6%
Num. Obs.	448	448	410	52	409

*Notes:* This table shows descriptive statistics for the change in EM bond prices and global banks' net worth around Lehman's bankruptcy (ten days before and three days after September 15, 2008). The first and second column reports changes in emerging-market log bond prices during ( $\Delta q_i$ ) and yield to maturities ( $\Delta ytm$ ) in this episode. The third column ( $\sum_j \theta_{ij}$ ) reports summary statistics of the shares held by these banks for the EM bonds included in the sample. The fourth column ( $\Delta n_j$ ) reports summary statistics of the change in global banks' log stock prices with reported holdings of emerging-market bonds included in the sample. The last column ( $\Delta n_i$ ) summarizes the change in bond holders' average net worth around the Lehman episode (defined as  $\Delta n_i = \sum_{j=1}^J \theta_{ij} \Delta n_j$ ).

episode, the average contraction in net worth of lenders for the bonds included in our sample is 12%. The standard deviation of this variable is 22%, suggesting enough variation exists in lenders' net worth across bonds to exploit in the empirical analysis.

### 2.3. Empirical Model and Results

Our empirical model studies the dynamic effects of global banks' net worth on bond prices using [Jorda's 2005](#) local projections:

$$\Delta_h y_{iks} = \alpha_{ks} + \beta_h \Delta n_i + \gamma' X_i + \varepsilon_{iks}, \quad (1)$$

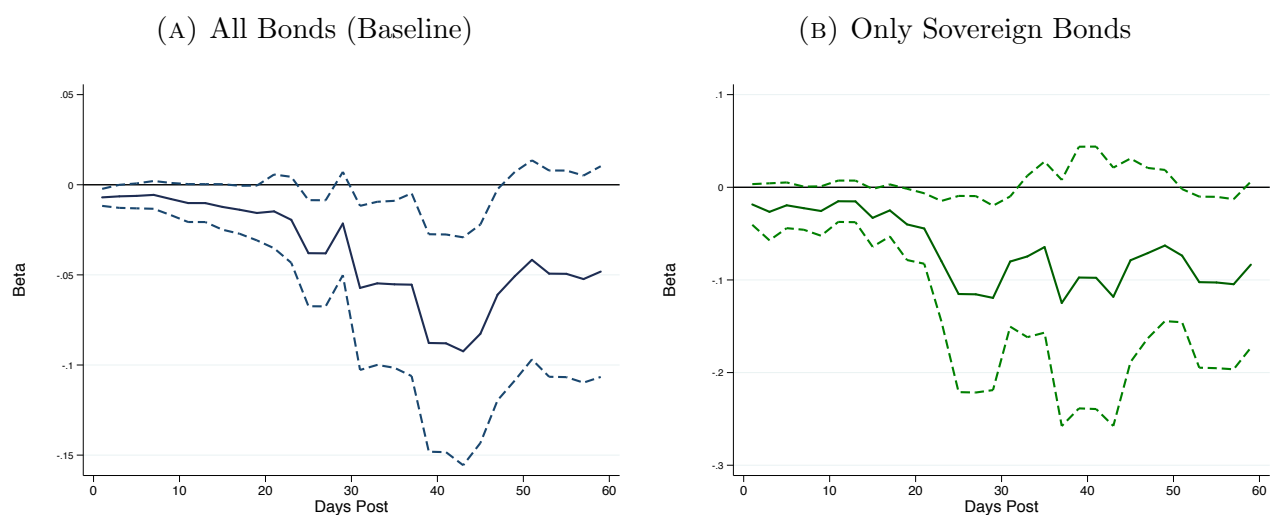
where  $\Delta_h y_{ik}$  denotes the change in the log gross yield to maturity or price of bond  $i$  issued by country  $k$  in sector  $s$  between the Lehman episode and  $h$  days after the episode,<sup>3</sup>  $\Delta n_i$  denotes the change in bond- $i$  holders' net worth around the Lehman episode (defined in the previous

<sup>3</sup>Sectors included are Government, Industrial, Financial, Utilities, Communication, Energy, and Others (including consumer, basic material, diversified, and technology). Appendix Table [A4](#) describes the bond share for each sector in our sample, highlighting that half of the bonds are sovereign.

subsection);  $\alpha_{ks}$  denotes country–sector fixed effects;  $X_i$  is a vector of controls at the bond level (including the total reported share  $\sum_{j=1}^J \theta_{ij}$ ); and  $\varepsilon_{iks}$  is a random error term. The coefficient of interest,  $\beta_h$ , measures the elasticity of bond prices to changes in holders’ net worth at horizon  $h$ . We estimate a separate regression for each horizon  $h$ , and cluster errors at the country level.

Panel (A) of Figure 2 presents the results from estimating (1) at different horizons for the bonds’ yield to maturities. Table A5 reports estimated coefficients and standard errors for selected horizons. Results indicate a positive estimated elasticity,  $\beta_h$ , indicating that bonds whose lender’s net worth contracted more during the Lehman episode experienced significantly higher yield to maturities in the two months after the episode. The estimated elasticity indicates that a 1% lower lender net worth translates into 0.05%–0.1% higher yield to maturities. Figure A2 and Table A6 shows similar results using bond prices in the left hand side of equation (1). To put this estimated coefficient into perspective, it implies that bonds whose holders suffer a contraction in net worth one standard deviation higher than the mean experienced a price contraction roughly twice as large as that of the average bond during the Lehman episode.

FIGURE 2. The Effect of Global Banks’ Net Worth on Emerging-Market Bond Yields



*Notes:* Panel (A) shows the estimated elasticity of bonds’ yield to maturities,  $\beta_h$ , to changes in the holder’s net worth at horizon  $h$  from estimating the regression 1. Solid lines represent the point estimates of the regression at each horizon, and dotted lines are the 90%-confidence intervals. Panel (B) shows the estimated coefficient in which 1 is estimated using only sovereign bonds.

Panel (B) of Figure 2 presents the results from estimating (1) using only sovereign bonds. The identification under this specification is stronger since sovereign bonds of the same country

arguably have the same default risk and this default risk is empirically captured by the country fixed effects. Results indicate a negative and similar point estimate with larger standard errors due to a lower number of observations.

A possible concern related to the results from model (1) is that banks more severely affected by the Lehman episode had a portfolio tilted towards more risky bonds, which experienced larger price drops during the crisis. Table 2 shows that banks that experienced low and high contractions in their net worth held portfolios of emerging-market bonds with similar maturity and liquidity (measured by their bid–ask spreads), characteristics typically associated with differential price sensitivities to shocks. Moreover, Appendix Table A7 shows that none of these bond-level variables depict a statistically significant relationship with holders’ change in net worth. Therefore, evidence shows little sorting of banks to particular EM bond characteristics that are relevant for their price dynamics. To provide further evidence that bond-level characteristics are not driving our results, Figure A3a presents the results from estimating (1) at different horizons including controls for initial level of default risk (captured by the pre-Lehman yield to maturity), maturity, liquidity, and bond amount. Results indicate a an estimated elasticity,  $\beta_h$ , very similar to those of our baseline results. In addition, we estimate (1) using only bonds with similar maturity.<sup>4</sup> Results, shown in Figure A3b, show a similar point estimate to the baseline specification.

As shall be seen in the next sections, this estimated coefficient can be used to discipline key aspects of the general-equilibrium model. In particular, given that during this period EM economies did not issue debt or conduct buybacks (see Appendix Figure A4), the estimated elasticity can be interpreted as the price effect in secondary markets to shocks that affect banks’ net worth. In our theoretical model, this coefficient will be linked to financial frictions experience by banks and to their marginal cost of raising external finance.

### 3. A MODEL OF THE GLOBAL ECONOMY

#### 3.1. *Environment*

The global economy consists of a continuum of DM economies and a continuum of heterogeneous EM economies. Households in these two types of economies differ in their preferences, giving rise to international lending. DM households are risk-neutral and patient, while EM households are risk-averse and impatient.

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<sup>4</sup>We consider bonds with maturities that range between half a year and two years. This specification has the best mapping to the model, since we model debt as one-year bonds.

TABLE 2. Emerging-Market Bonds' Characteristics  
by Holders' Change in Net Worth

	$\Delta n_i < \Delta \bar{n}_i$	$\Delta n_i > \Delta \bar{n}_i$
Residual maturity	395 [63]	304 [41]
Bid-ask spread	0.4% [0.02]	0.5% [0.03]
Amount issued	0.067 [0.073]	-0.034 [0.034]
Amount outstanding	0.096 [0.077]	-0.049 [0.038]

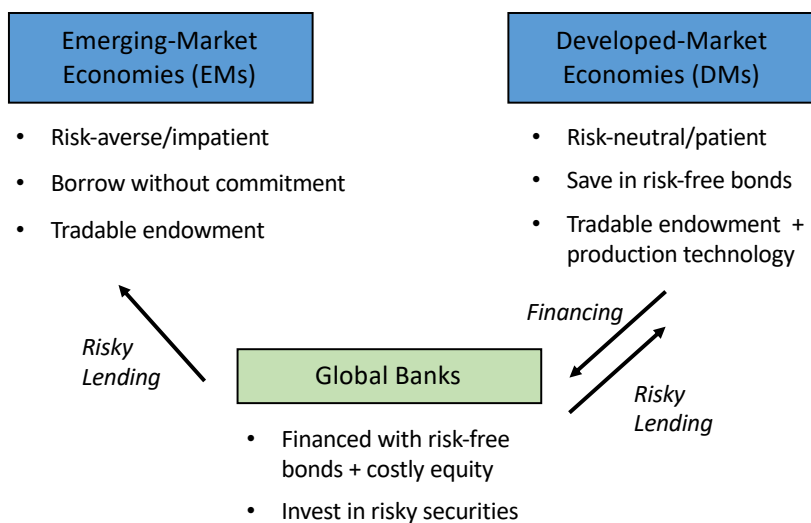
*Notes:* This table shows the mean maturity, bid–ask spread, amount issued, and amount outstanding of bonds held by banks whose net worth contracted by less than the mean ( $\Delta n_i < \Delta \bar{n}_i$ ) and more than the mean ( $\Delta n_i > \Delta \bar{n}_i$ ). Maturity is expressed in days. Amounts are expressed as log deviations from country–sector mean. Standard errors are in brackets.

The key feature of the model is that international lending is mediated by global banks. Households in DMs provide finance to global banks using a risk-free bond (“deposits”) and equity. Global banks face frictions in their intermediation activity that limit their ability to raise funds from DMs. They use these funds to lend to EM households using risky bonds and/or invest in risky DM technologies.

Households in EMs receive each period a stochastic endowment of tradable goods, which has a systemic component (common across all EMs) and an idiosyncratic component (whose realizations differ across EMs). EM households lack commitment to repay their debt. We interpret household borrowing in a broad sense, capturing direct international borrowing, sovereign borrowing, or borrowing through other agents (e.g., local banks). Figure 3 graphically represents the global economy.

Time is discrete and infinite. Within each period, the timing is as follows. At the beginning of each period, exogenous variables are realized. Global banks repay outstanding deposits, issue new deposits, raise equity (or pay dividends) and trade outstanding assets among each other. Then risky securities are repaid, banks can pay dividends or raise equity, and purchase newly issued risky securities. This timing gives rise to the presence of a primary and secondary market

FIGURE 3. The Global Economy



for risky securities. The secondary market is useful to make an explicit connection between the model and our empirical results.

### 3.2. Developed Economies

*Households.* The representative DM household has preferences described by the lifetime expected utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{\text{DM}}^t c_{\text{DM}t}, \quad (2)$$

where  $c_{\text{DM}t}$  denotes consumption and  $\beta_{\text{DM}} \in (0, 1)$  the DM household's subjective discount factor.

Each period, households receive an endowment of tradable goods  $y_{\text{DM}}$  and time to work  $\bar{h}$ . They can save in deposits in global banks that pay a return  $R_{dt}$  for every unit of deposit in  $t + 1$ . Their sequential budget constraint is given by

$$c_{\text{DM}t} = y_{\text{DM}} + w_t \bar{h} + R_{dt} d_t - d_{t+1} + \pi_t \quad (3)$$

where  $w_t$  denotes wages in period  $t$ ,  $d_{t+1}$  denotes the amount of deposits in  $t$  to be repaid in  $t + 1$ , and  $\pi_t$  denotes net payouts from global banks.

The DM household's problem is to choose state-contingent plans  $\{c_{\text{DM}t}, d_{t+1}\}_{t=0}^{\infty}$  to maximize (2) subject to (3), taking as given prices  $\{R_{dt}, w_t\}_{t=0}^{\infty}$  and transfers  $\{\pi_t\}_{t=0}^{\infty}$ . Household's optimization delivers a constant equilibrium interest rate for deposits,  $R_{dt} = \beta_{\text{DM}}^{-1}$ .

*Nonfinancial firms.* DM economies are also populated by a continuum of nonfinancial firms, which have access to technologies to produce tradable goods  $y_{ft}$ , and accumulate capital  $k_{ft+1}$ , given, respectively, by

$$y_{ft} = (\omega_t \epsilon_{ft} k_{ft})^\alpha h_{ft}^{(1-\alpha)}, \quad (4)$$

$$k_{ft+1} = \omega_t \epsilon_{ft} (1 - \delta) k_{ft} + i_{ft}, \quad (5)$$

with  $\alpha, \delta \in (0, 1)$ , where  $h_{ft}$  are hours of work hired by firm  $f$ ,  $i_{ft}$  is firm investment, and  $\omega_t$  and  $\epsilon_{ft}$  are aggregate and idiosyncratic exogenous shocks to the capital quality. We assume both shocks have bounded support and that  $\epsilon_{ft}$  is i.i.d across firms. Firms are owned by global banks, as we describe later.

### 3.3. Global Banks

Global banks are financial firms owned by DM households, which engage in financial intermediation and trading in the world economy. Their objective is to maximize the lifetime discounted payouts transferred to DM households,

$$\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta_{\text{DM}}^{s-t} \pi_{jt+s}, \quad (6)$$

where  $\pi_{jt}$  denotes net payments of bank  $j$  to households in period  $t$ . When primary markets open, banks use their “cash on hand”,  $x_{jt}$ , i.e., units of final goods obtained from previous investments, to purchase risky securities and pay dividends,  $div_{jt}$

$$\int_{i \in \mathcal{I}_t} q_{\text{EM}t}^i a_{\text{EM}jt+1}^i di + q_{\text{DM}t} a_{\text{DM}jt+1} + div_{jt} = x_{jt} \quad (7)$$

where  $\{a_{\text{EM}jt+1}^i\}_{i \in \mathcal{I}_t}$  denote bonds issued by EM economies in period  $t$  to be repaid in period  $t + 1$ ,  $i$  indexes a particular EM economy and  $\mathcal{I}_t$  the set of EM economies that issue bonds in period  $t$ ,  $a_{\text{DM}jt+1}$  denote claims on the profits of nonfinancial firms from DM economies, and  $\{q_{\text{EM}t+1}^i, q_{\text{DM}t}\}$  denote their prices. Although banks can raise equity to finance the purchase of their risky assets (i.e.,  $div_{jt} < 0$ ), we assume that raising equity is a costly source of financing, entailing a cost of  $\mathcal{C}(-div_{jt}, n_{jt})$  units of final goods per unit raised, with  $\mathcal{C}(div, n) = \phi\left(\frac{-div}{n}\right)$  and where  $n_{jt}$  is the net worth of the bank in the primary market. As stressed in the corporate finance literature, these costs are aimed at capturing flotation costs and adverse selection premia associated with raising external equity (see, for example, [Hennessy and Whited, 2007](#)).

The set of securities purchased by banks in the primary markets, determine the portfolio with which banks arrive to the secondary market of the following period. We assume that secondary markets are organized in “trading networks,” indexed by  $\ell \in [0, 1]$ . Each bank is part of a

trading network and can only trade securities with other banks of the network at market prices  $\{q_{\text{EM}jt}^i(\ell)\}_{i \in \mathcal{I}_t}$  for EM securities and  $q_{\text{DM}jt}(\ell)$  for DM securities. This implies that the net worth of a bank in the secondary market is given by

$$\tilde{n}_{jt} = \int_{i \in \mathcal{I}_{t-1}} q_{\text{EM}t}^i(\ell) a_{\text{EM}jt}^i \, di + q_{\text{DM}t}(\ell) a_{\text{DM}jt} - R_{dt} d_t, \quad (8)$$

where  $d_{jt}$  is the amount of deposits that banks need to repay in period  $t$ , issued in  $t - 1$ . At this stage banks can issue new deposits,  $d_{jt+1}$ , raise additional equity,  $-\tilde{d}i v_{jt}$  and purchase/sell risky assets. This means that at the beginning of a given period  $t$ , the flow-of-funds constraint of a bank in trading network  $\ell$  is given by

$$\int_{i \in \mathcal{I}_{t-1}} q_{\text{EM}t}^i(\ell) \tilde{a}_{\text{EM}jt}^i \, di + q_{\text{DM}t}(\ell) \tilde{a}_{\text{DM}jt} + \tilde{d}i v_{jt} = \tilde{n}_{jt} + d_{jt+1}, \quad (9)$$

where  $\{\tilde{a}_{\text{EM}jt}^i\}$  and  $\tilde{a}_{\text{DM}jt}$  denote, respectively, bonds issued by EM economies and claims on nonfinancial firms from DM economies to be repaid in period  $t$ , acquired by bank  $j$  in period- $t$ 's secondary market.

As in the primary market, raising equity entails a cost of  $\mathcal{C}(-\tilde{d}i v_{jt}, \tilde{n}_{jt})$  units of final goods per unit raised. Additionally, banks face also financial frictions in the deposit market, linking deposits to their cash on hand,

$$d_{jt+1} \leq \kappa x_{jt}, \quad (10)$$

where  $\kappa \in (0, 1)$ .

The set of securities purchased in secondary markets determines a bank's cash on hand and net worth after securities are repaid:

$$x_{jt} = \int_{i \in \mathcal{I}_{t-1}} R_{\text{EM}t}^i(\ell) q_{\text{EM}t}^i(\ell) \tilde{a}_{\text{EM}jt}^i \, di + R_{\text{DM}t}(\ell) q_{\text{DM}t}(\ell) \tilde{a}_{\text{DM}jt}, \quad (11)$$

$$n_{jt} = x_{jt} - d_{jt+1}, \quad (12)$$

where  $\{R_{\text{EM}t}^i(\ell)\}_{i \in \mathcal{I}_{t-1}}$  is the set of returns of EM bonds purchased in secondary markets in period  $t$  in trading network  $\ell$  and  $R_{\text{DM}t}(\ell)$  is the return of the claims of nonfinancial firms in DM economies purchased in secondary markets in period  $t$  in trading network  $\ell$ . We assume that trading networks differ in the realization of the shock to the capital quality  $\omega_t(\ell) \equiv \omega_t \epsilon_t(\ell)$  where  $\epsilon_t(\ell)$  is the average idiosyncratic shock to the quality of capital of those firms financed by banks in the trading network. We assume  $\epsilon_t(\ell)$  i.i.d distributed across trading networks with mean one. Given the presence of trading and financial frictions, the dispersion in the returns of DM investments induce variation in secondary-market prices across trading networks. Finally,

after assets are repaid banks receive an i.i.d. exit shock which occurs with probability  $1 - \sigma$ . Banks that exit repay outstanding deposits and transfer the net proceedings to their owners.<sup>5</sup> The net payouts to DM households in a given period are given by

$$\pi_{jt} = \tilde{div}_{jt}(1 + \mathbb{I}_{\tilde{div}_{jt} < 0} \mathcal{C}(\tilde{div}_{jt}, \tilde{n}_{jt})) + div_{jt}(1 + \mathbb{I}_{div_{jt} < 0} \mathcal{C}(div_{jt}, n_{jt})). \quad (13)$$

The problem of a global bank  $j$  in trading network  $\ell$  is to choose state-contingent plans  $\{((\tilde{a}_{EMjt}^i, a_{EMjt+1}^i)_{i \in [0,1]}, \tilde{a}_{DMjt}, a_{DMjt+1}, div_{jt}, d_{jt+1})\}_{t=0}^{\infty}$  to maximize (6) subject to flow of funds and financial constraints (7) - (13). Appendix C shows the bank's recursive problem. Our formulation gives rise to a problem that is linear in the banks' state variables, and whose solution is characterized by the following asset pricing conditions and equity choices for the primary market

$$R_{EMt}^e = R_{DMt}^e, \quad (14)$$

$$-2\phi \left( \frac{div_{jt}}{n_{jt}} \right) = \beta_{DM} R_{DMt}^e - 1, \quad (15)$$

for any solution with  $a_{jEMt+1}^i > 0$ ,  $a_{jEMt+1} > 0$ , where  $R_{EMt}^e \equiv \mathbb{E}_t[\nu_{t+1} R_{EMt+1}^i]$ ,  $R_{DMt}^e \equiv \mathbb{E}_t[\nu_{t+1} R_{DMt+1}]$ ,  $R_{EMt+1}^i$  and  $R_{DMt+1}$  denote the returns in period  $t+1$  of a security purchased in primary markets in period  $t$ , and  $\nu_t$  is the marginal value of net worth for global banks in the primary market (formally defined in Appendix C). Equation (14) implies that global banks equate expected risk-adjusted returns across risky assets in their purchase of securities in the primary market. Equation (15) implies that the banks raises external finance until its marginal cost equals the marginal benefit of investing in risky securities. Importantly, when expected returns on risky securities are higher, banks optimally choose to issue more equity.

Similarly, the solution to the banks' problem is characterized by constraint (10) holding with equality and the following asset pricing conditions and equity choices for the secondary market

$$R_{EMt}(\ell) = R_{DMt}(\ell) \quad (16)$$

$$-2\phi \left( \frac{\tilde{div}_{jt}}{\tilde{n}_{jt}} \right) = \frac{\tilde{\nu}_t R_{DMt}(\ell)}{1 - \kappa R_{DMt}(\ell)} - 1 \quad (17)$$

for any solution with  $\tilde{a}_{jEM}^i > 0$ ,  $\tilde{a}_{jEM} > 0$ , and  $\tilde{\nu}_t$  is the marginal value of net worth for global banks in the secondary market (also formally defined in Appendix C). Equation (16) implies equal returns across risky assets in the secondary market. Equation (17) implies that

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<sup>5</sup>If the proceeding of selling assets is less than the promised repayments to deposits, banks' owners transfer resources to deposits holders. Each period new banks enter to the economy, endowed with units of the final good  $\bar{n}$ , and the total mass of global banks is always fixed at one.



the banks raises external finance until its marginal cost equals the marginal benefit of investing in risky securities. In this case the marginal benefit is enhanced by the fact that banks can also lever up their assets through deposits. Importantly, just like in the primary market, when returns on risky securities in the secondary market are higher, banks optimally choose to issue more equity.

### 3.4. *Emerging Economies*

Each emerging economy is populated by a mass one of identical households with preferences described by the lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{EM}^t u(c_{it}) \quad (18)$$

where  $u(\cdot)$  is increasing and concave,  $c_{it}$  denotes consumption of the representative household of EM  $i \in [0, \eta_{EM}]$  in period  $t$  and  $\beta_{EM} \in (0, \beta_{DM})$  is the subjective discount factor of EM households. Each period, EM households receive a stochastic endowment of tradable goods, with a systemic component  $y_{EMt}$ , common across all EMs, and an idiosyncratic component  $z_{it}$ . After observing the realization of their endowment, households choose to repay debt they inherited from the previous period ( $\iota_{it} = 0$ ) or to default ( $\iota_{it} = 1$ ). Defaulting households lose access to external credit markets and reenter when the random variable  $\zeta_{it} \sim \text{Bernoulli}(\theta)$  equals one. This implies that households remain in financial autarky for a stochastic number of periods. Households that repay their previous promises can issue one-period bonds, whose promised payments are not state contingent, facing a bond-price schedule  $q_{iEMt}(b_{it+1})$  that depends on the EM characteristics and borrowing choices. Their sequential budget constraint is

$$c_{it} = y_{EMt} + z_{it} + q_{iEMt}^i(b_{it+1})b_{it+1} - b_{it}. \quad (19)$$

Households excluded from global capital markets simply consume their endowments

$$c_{it} = \mathcal{H}(y_{EMt} + z_{it}), \quad (20)$$

where  $\mathcal{H}(x) \leq x$  captures the output losses associated with the default decision. The household problem in recursive form is detailed in Appendix C.

In partial equilibrium, this problem is equivalent to a standard borrowing problem in a small open economy with default (see [Arellano, 2008](#)). However, the bond-price schedule faced by EM households in this economy will be affected by the interaction between global banks, the distribution of debt positions across EMs, and systemic variables introduced by our framework.

### 3.5. Equilibrium

Definition 1 defines a competitive equilibrium in the global economy.

**DEFINITION 1.** *Given global banks' initial portfolios  $((a_{EMj0}^i)_{i \in [0, \eta_{EM}]}, a_{DMj0}, d_{j,0})_{j \in [0,1]}$ , EM households' initial debt positions  $(b_{it})_{i \in [0, \eta_{EM}]}$ , and state-contingent processes  $\{(\omega(\ell))_{\ell \in [0,1]}, y_{EMt}, (z_{it}, \zeta_{it})_{i \in [0, \eta_{EM}]}\}$ , a competitive equilibrium in the global economy is a sequence of prices  $\{w_t, ((q_{EMt}^i(\ell))_{\ell \in [0,1]}, q_{EMt}^i(b_{t+1}))_{i \in [0, \eta_{EM}]}, ((q_{DMt}(\ell))_{\ell \in [0,1]}, q_{DMt})\}_{t=0}^\infty$  and allocations for DM households  $\{c_{DMt}, d_{t+1}\}_{t=0}^\infty$ , nonfinancial firms  $\{(h_{ft}, k_{ft+1})_{f \in [0,1]}\}_{t=0}^\infty$ , global banks  $\{((\tilde{a}_{EMjt}^i, a_{EMjt+1}^i)_{i \in [0,1]}, \tilde{a}_{DMjt}, a_{DMjt+1}, d_{jt+1})_{j \in [0,1]}\}_{t=0}^\infty$ , and EM households  $\{(c_{it}, b_{it+1}, \iota_{it})_{i \in [0, \eta_{EM}]}\}_{t=0}^\infty$  such that*

- i. Allocations solve agents problems at the equilibrium prices,*
- ii. Assets and labor markets clear.*

Without loss of generality, we focus on an equilibrium in which the all securities issued by a particular EM are purchased by banks in a given trading network. This guarantees that each EM bond is traded in one trading network only in the secondary market.<sup>6</sup> In equilibrium, clearing in the primary asset market implies that global bank's investment in each risky security traded in the global economy equalizes the amount of that type of securities issued:

$$q_{EMt}^i A_{EMit+1} \equiv \int_{j \in [0,1]} q_{EMt}^i a_{EMjt+1}^i dj = q_{EMt}^i (b_{it+1}) b_{it+1},$$

$$q_{DMt} A_{DMt+1} \equiv \int_{j \in [0,1]} q_{DMt} a_{DMjt+1} dj = k_{t+1}.$$

On the other hand, in the secondary market there is no issuance and hence market clearing implies that the amount of securities traded coincides with those issued in the prior primary market:

$$\tilde{A}_{EMit+1}(\ell) \equiv \int_{j \in \mathcal{J}(\ell)} \tilde{a}_{EMjt+1}^i dj = A_{EMit+1},$$

$$\tilde{A}_{DMt+1}(\ell) \equiv \int_{j \in \mathcal{J}(\ell)} \tilde{a}_{DMjt+1} dj = \int_{j \in \mathcal{J}(\ell)} a_{DMjt+1} dj,$$

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<sup>6</sup>This feature, together with the assumption that each EM issues only one type of bond imply that if one were to run our empirical regression on secondary market prices in the model, the country fixed effects would capture all the variation in secondary market prices. This can be solved by introducing the possibility for EMs of issuing different varieties of bonds which have the same repayment, but can be traded in different islands. Given that the allocations of both models are identical, we focus on the simpler model presented here to ease exposition.

where  $\mathcal{J}(\ell)$  denotes the set of banks in trading network  $\ell$ . The returns of securities purchased in primary markets are given by  $R_{EMit+1} = \frac{\iota_{it+1}}{q_{EMt}^i(b_{it+1})}$  and  $R_{DMt+1}(\ell) = \frac{\omega_{t+1}(\ell)[\alpha A_{DMt}^{\alpha-1} + (1-\delta)]}{q_{DMt}}$ . Similarly, the returns of purchasing securities in the secondary market are given by  $R_{EMit+1}(\ell) = \frac{\iota_{it+1}}{q_{EMt+1}^i(\ell)}$  and  $R_{DMt+1}(\ell) = \frac{\omega_{t+1}(\ell)[\alpha A_{DMt+1}^{\alpha-1} + (1-\delta)]}{q_{DMt+1}(\ell)}$ .

#### 4. GLOBAL SUPPLY AND DEMAND FOR EM DEBT

We discuss theoretically the channels through which global banks affect EM debt, in both secondary and primary markets. For this, we consider an economy without aggregate uncertainty, and study the effects of fully unanticipated aggregate shocks, with perfect foresight transitional dynamics back to steady state. We incorporate a stochastic structure for aggregate shocks in the next section, where we analyze the quantitative version of our model.

##### 4.1. *Equilibrium in the Secondary Market of Risky-Debt*

In the secondary market the outstanding stock of securities is fixed from previous issuance and the equilibrium rate of return should be such that the excess supply of funds, or demand of additional securities, is zero. The excess supply of funds to an EM  $i$  is obtained by aggregating the flow of funds constraints (8) and (9) for all banks in a given trading network and is given by<sup>7</sup>

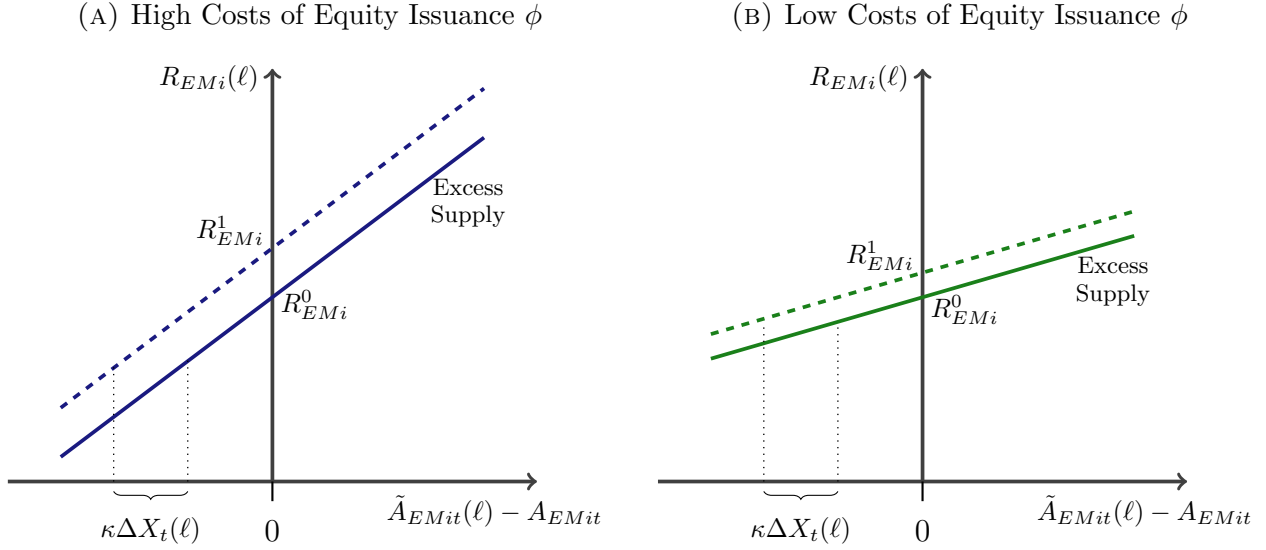
$$q_{EMt}(\ell) \left( \tilde{A}_{EMit}(\ell) - A_{EMit} \right) = \underbrace{\kappa X_t(\ell) - R_d D_t}_{\text{New deposit flow}} + \underbrace{\tilde{\mathcal{E}}(R_{EMit}(\ell), \phi)}_{\text{Equity issuance}}. \quad (21)$$

The excess supply is increasing in required returns in the secondary market since optimal equity issuance is increasing in returns as pointed in (17). If returns are higher banks are willing to increase their equity issuance to lend more funds to EMS by purchasing additional securities. Equilibrium in the secondary market is depicted in Figure 4.

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<sup>7</sup>The excess supply uses market clearing in the market for the remaining  $DM$  and  $EM$  securities in that trading network.

FIGURE 4. Equilibrium in the Secondary Market



Consider now a negative realization of  $X_t(\ell)$  in a particular trading network, due to lower repayments from DM or EM investments, i.e., a low  $\epsilon_t(\ell)$ . A lower  $X_t(\ell)$  reduces the amount of deposits that banks can rollover. This implies that banks have less resources available to purchase securities in the secondary market, which reduces the excess supply of funds for a given required return, as depicted in the dotted line in Figure 4a, and increases the equilibrium required return. The mechanics of this shock is better understood with the following example. Consider a mass of banks in a trading network that experience a drop in  $x_t$ . These banks now need to sell part of their assets to delever in order to satisfy their borrowing constraint. In order to purchase these assets, the other banks in the trading network need to issue new equity, and they are willing to do so if the return from purchasing the assets is higher. Therefore, a negative shock to  $X_t(\ell)$  triggers a fire sale on risky securities.

How much secondary market prices respond to shocks to  $X_t(\ell)$  depends on the banks' ability to recapitalize, which in the model is captured by the parameter  $\phi$  that determines the marginal cost of issuing equity. Consider an economy with high costs of equity issuance (high  $\phi$ ). In this economy the excess supply of funds is steep, since banks require a significant increase in returns in order to issue equity to finance purchases of additional risky securities. As shown in Figure 4a, a shock to  $X_t(\ell)$  will have associated a large drop in prices, and a large increase in required returns, to induce equity issuance to purchase the outstanding stock of securities. Consider now an economy with low  $\phi$ . In this economy it is less costly for banks to recapitalize and therefore prices and returns need to respond less to a shock to  $X_t(\ell)$  of the same magnitude,

in order to induce equity issuance to restore equilibrium. This can be seen in Figure 4b. In the extreme case in which banks can recapitalize costlessly the excess supply becomes perfectly elastic and there would be no effects of  $X_t(\ell)$  on prices. This analysis suggests that the degree of price drops in response to shocks to banks' net worth is informative of the degree of financial frictions that banks face.

#### 4.2. Equilibrium in the Primary Risky-Debt Market

Equilibrium in the primary market for EM borrowing can also be characterized with a demand–supply of funds scheme. On the lender side, combining optimal portfolio and financing choices across banks, we obtain a positive relationship between EMs' required returns and aggregate EM bonds acquired by global banks, which we label *aggregate supply* of funds to EM.<sup>8</sup>

$$\begin{aligned} \mathcal{A}_t^s(R_{\text{EM}t}^e, X_t) &\equiv \int_{i \in \mathcal{I}+t} \int_{j \in [0,1]} q_{\text{EM}t}^i a_{\text{EM}jt+1}^i \, dj \, di \\ &= \underbrace{X_t + \mathcal{E}(R_{\text{EM}t}^e, \phi)}_{\substack{\text{Cash on hand} \\ + \text{Equity issuance}}} - \underbrace{\{[R_{\text{EM}t}^e - (1 - \delta)] (\omega_{t+1} \alpha)^{-1}\}^{\frac{1}{\alpha-1}}}_{\text{Investment in DM firms}}, \end{aligned} \quad (22)$$

where  $X_t \equiv \int_{j \in [0,1]} x_{jt} \, dj$  denotes the aggregate cash on hand of banks engaged in lending in period  $t$ , and  $\mathcal{E}(R_{\text{DM}t}^e, \phi) \equiv - \int_{j \in [0,1]} \text{div}_{jt} \, dj$  denotes the aggregate equity raised by banks. This relationship between funds supplied and required returns is increasing (i.e.,  $\frac{\partial \mathcal{A}_t^s}{\partial R_{\text{EM}t}^e} > 0$ ). In order to increase the amount of funds supplied, banks either need to issue more equity or divert funds from DM investments, both of which require higher returns. Issuing more equity is costly due to its increasing marginal costs, and diverting funds from DM firms is costly because it depresses the aggregate level of capital and increases its marginal product. Similarly to the secondary market, the degree of financial frictions, captured by the parameter  $\phi$ , is relevant determining the elasticity of the aggregate supply of funds. If raising equity is costlier in the margin, banks will require a higher return for purchasing an additional security in the margin. The supply elasticity in the primary market is also affected by the degree of decreasing returns in DM firms,  $\alpha$ . To understand this, consider the case of infinite costs of issuing equity. In this case the only way to purchase more EM securities is by reducing the investment in DMs, but this decreases capital and increases its marginal product. How much its marginal product increases depends on the degree of decreasing returns. Finally, the aggregate cash on hand

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<sup>8</sup>This supply is composed by aggregating the supply of funds to each EM economy. The analysis allows for aggregation at this level since the optimal portfolio allocation of global banks implies equal required returns.

of global banks acts as an aggregate supply shifter: for a given level of EM returns, a higher global-bank cash on hand leads to more funds invested in EMs.

On the borrower side, aggregating borrowing across EMs and using the definition of returns, we obtain a relationship between required return and borrowing in EMs, which we label *aggregate demand* of funds:

$$\mathcal{A}_t^d(R_{\text{EM}t}^e) = \int_{i \in \mathcal{I}_t} \frac{1}{R_t^e} \iota_{it+1} b_{it+1} di. \quad (23)$$

The slope of aggregate demand is given by  $\frac{\partial \mathcal{A}_t^d(R_{\text{EM}t}^e)}{\partial R_{\text{EM}t}^e} = -\frac{1}{R_t^{e2}} \iota_{it+1} b_{it+1} + \frac{1}{R_t^e} \partial \frac{\partial \iota_{it+1} b_{it+1}}{\partial R_t^e}$ . The first term of this expression is negative, reflecting that higher required returns are associated with lower debt prices and less borrowing for given repayments. The second term reflects the effect of required return on the next period's repayment choices. Although this term cannot be signed analytically, we focus here on a case in which it is negative, as it will be in our quantitative model, reflecting that higher required return reduces borrowing and makes repayments less likely.

Figure 5 depicts the equilibrium aggregate borrowing and required returns as the intersection between aggregate demand and supply of funds, for given levels of global banks' cash on hand. Cash on hand, however, is also endogenous in this system, as required returns affect borrowers' repayments and realized returns. To obtain this relationship, we integrate the evolution of cash on hand (11) across banks:

$$X_t = (1 - \sigma) \int_{i \in \mathcal{I}_{t-1}} \iota_{it} A_{\text{EM}it} di + R_{\text{DM}t} A_{\text{DM}t} + \bar{n}. \quad (24)$$

Given previous-period investments  $\{(A_{\text{EM}it})_{i \in [0,1]}, A_{\text{DM}t}\}$ , the slope of cash on hand with respect to required returns is given by  $\frac{\partial X_t}{\partial R_{\text{EM}t}^e} = \int_{i \in \mathcal{I}_{t-1}} \frac{\partial \iota_{it}}{\partial R_{\text{EM}t}^e} A_{\text{EM}it} di$ . We focus on the case in which this slope is negative, as it will be in our quantitative model, reflecting that higher required returns decrease the value of repayment and leads to more default in EMs (Figure 5, right panel). Together, aggregate supply, aggregate demand, and the evolution of cash on hand constitute a system of three equations determining aggregate EM borrowing,  $A_{\text{EM}t}$ , required returns,  $R_{\text{EM}t}^e$ , and global banks' aggregate cash on hand,  $X_t$ .

### 4.3. Aggregate shocks and EM borrowing costs

We now use our equilibrium scheme to analyze global banks' role in propagating aggregate shocks. First, consider the effect of an unexpected negative shock to the return of the DM security. This shock affects global banks' cash on hand and, through this channel, the aggregate supply of funds (see equations (22) and (24)). The initial effect of this shock is represented in

FIGURE 5. The Global Debt Market Equilibrium

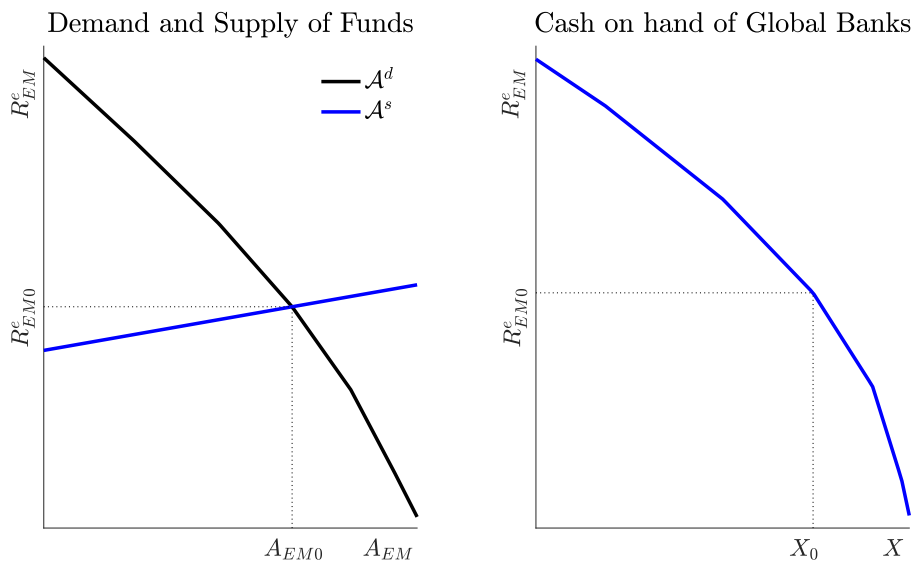


FIGURE 6. Aggregate Shocks and Global Debt Market Equilibrium

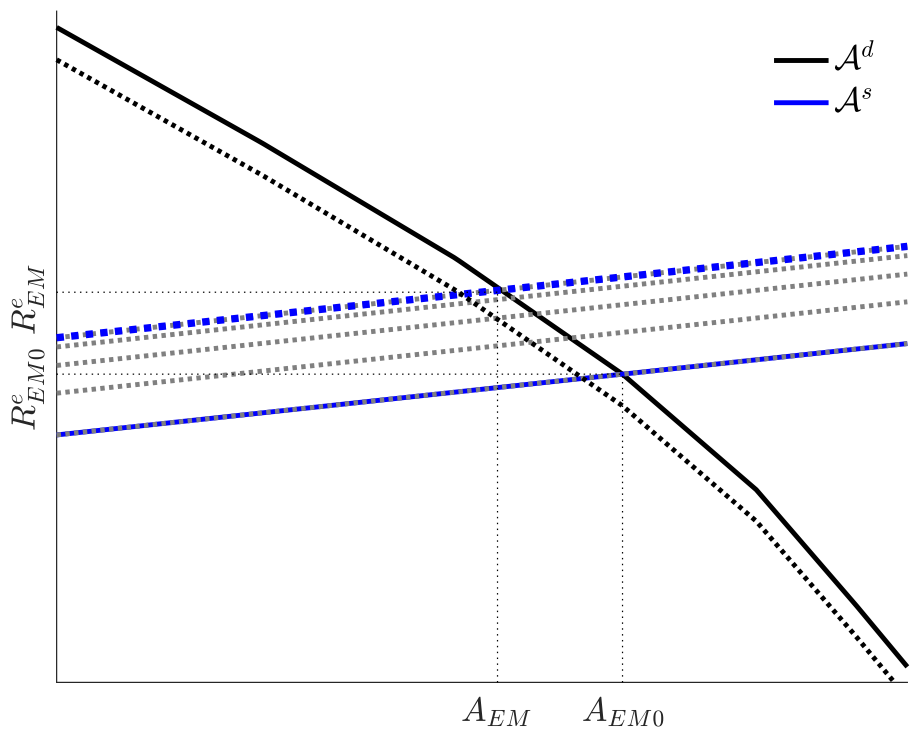


Figure 6 as a shift of the net-worth and aggregate-supply curves, indicating lower cash on hand and lower supply of funds for any given level of EM required returns, leading to an increase in EM required returns.

Through a similar mechanism, global banks also amplify systemic shocks originating in EMs. For this, consider now the effect of an unexpected negative shock to systemic EM income. The negative income shock leads more EM economies to default, affecting banks' cash on hand and the supply of funds in a fashion similar to that analyzed above for the shock to the realized return of DM securities. The negative income shock also affects funds demand. In Figure 6, this is represented as a downward shift in the aggregate demand of funds, as typically occurs in models of risky external borrowing. If the increase in required returns driven by the contraction in aggregate supply is not fully offset by a weaker demand, global banks trigger the amplification through cash on hand explained above. The amplification through global banks is a key difference between systemic and idiosyncratic EM income shocks. When income shocks are idiosyncratic, they do not affect global banks' cash on hand and have a smaller effect on debt prices.

## 5. QUANTITATIVE ANALYSIS

In this section, we calibrate the model to match the salient features of global banks and the EM risky-debt market. Importantly, the calibration is informed by the empirical results from Section 2. We then use our quantified model to assess the relevance of global banks as lenders to emerging economies.

### 5.1. Calibration

One period corresponds to one year. The EM households' period utility function is

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}.$$

The EM households' endowment processes are

$$\begin{aligned} \ln y_{EMt} &= \rho_{yEM} \ln y_{EMt-1} + \sigma_{yEM} \epsilon_{EMt}, & \epsilon_{EMt} &\sim N(0, 1), \\ \ln z_{it} &= \rho_{z_i} \ln z_{it-1} + \sigma_{zEM} \epsilon_{it}, & \epsilon_{it} &\sim N(0, 1). \end{aligned}$$

Similarly, the process of quality of capital in DM firms is

$$\ln \omega_t = \rho_\omega \ln \omega_{t-1} + \sigma_\omega \epsilon_{\omega t}, \quad \epsilon_{DMt} \sim N(0, 1).$$

Finally, the output net of default costs is parametrized by

$$\mathcal{H}(y) = y(1 - d_0 y^{d_1}).$$

where  $d_0, d_1 \geq 0$ . This functional form delivers higher nonlinear default costs for higher values of  $y$  (Arellano, 2008; Chatterjee and Eyigungor, 2012).



The model calibration features a set of parameters which we set exogenously and another set which we calibrate to match relevant moments. We stress the role of two key parameters,  $\phi$  and  $\eta_{EM}$ , that govern how elastic is the supply of funds to EMs by global banks, and the share of EM debt in the asset portfolio of global banks, respectively. We first describe the set of predetermined parameters that are reported in the first column of Table 3. We follow the literature on quantitative macroeconomic models to set values for the exogenous parameters. The coefficient of risk aversion of EM households is set to  $\gamma = 2$ . The probability of re-entering credit markets is set to  $\theta = 0.25$ , so that the average exclusion period is of 4 years, in line with empirical evidence (Gelos et al. (2011) and Dias and Richmond (2008)). The parameters of the endowment process of EM households are estimated using data on output for the sample of countries analyzed in section 2. We restrict the systemic and idiosyncratic component of output to have the same stochastic process, i.e.  $\rho_{y_{EM}} = \rho_{z_{EM}}$  and  $\sigma_{y_{EM}} = \sigma_{z_{EM}}$ . We make this parametric restriction to study the differential effects of these shocks that arise due to endogenous amplification, rather than due to having different stochastic processes. The estimated values of the autocorrelation and standard deviation are  $\rho_{y_{EM}} = \rho_{z_{EM}} = 0.68$  and  $\sigma_{y_{EM}} = \sigma_{z_{EM}} = 0.03$ . The discount factor of DM households is  $\beta_{DM} = 0.98$  which implies an annual risk-free interest rate of 2%. The depreciation rate is set at  $\delta = 0.15$ , and the share of capital to  $\alpha = 0.35$ . Finally, we set the parameter on global banks' borrowing constraint to  $\kappa = 0.9$ , to target a ratio of net worth-to-assets of 10%. This capital ratio is obtained by analyzing the balance sheets of seven major global banks: Banco Santander, HSBC, Citibank, Bank of America, JP Morgan, and Wells Fargo. Figure A8 reports this and other relevant statistics regarding those banks' balance sheets.

The remaining parameters are calibrated to match specific data moments. Some of these parameters are related EM households ( $\beta_{EM}, d_0, d_1, \eta_{EM}$ ), others to global banks ( $\phi, \sigma$ ), and others to DM firms ( $\rho_\omega, \sigma_\omega$ ). We target moments related to EM debt service and default, to global banks, and to other risky assets. Related to EM debt, we target the average annual service of external debt, the annual rate of default, the average spread, the average correlation of spreads and output, and the average volatility of spreads.<sup>9</sup> Related to global banks and other

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<sup>9</sup>The average level of debt in the data is computed as the average annual service of external debt of the countries in our sample for the period Sep-96 to Dec-14. The annual rate of default is computed as the average share of EM defaults that occurred in our sample period. The average level and volatility of spreads is computed as the country-time average of sovereign spreads. Its correlation with output is computed as the average correlation of sovereign spreads and the cyclical component of output for each country in our sample. We compute global banks' average exposure to DM risky assets as the exposure to all risky assets that are not

TABLE 3. Model Calibration

Parameter	Description	Value
<i>Exogenous Parameters</i>		
$\gamma$	risk aversion	2
$\theta$	re-entry probability	0.25
$\rho_{y_{EM}}$	systemic endowment autocorrelation	0.68
$\sigma_{y_{EM}}$	systemic endowment shock volatility	0.03
$\rho_{z_{EM}}$	idiosyncratic endowment autocorrelation	0.68
$\sigma_{z_{EM}}$	idiosyncratic endowment shock volatility	0.03
$\beta_{DM}$	discount rate of DM	0.98
$\alpha$	share of capital	0.35
$\delta$	depreciation	0.15
$\kappa$	debt-to-asset ratio	0.90
<i>Calibrated Parameters</i>		
$\beta_{EM}$	discount rate of EMs	0.85
$d_0$	default cost - level	0.03
$d_1$	default cost - curvature	1.6
$\sigma$	bank survival rate	0.96
$\phi$	marginal cost of raising equity	10
$\eta_{EM}$	mass of EM economies	7.2
$\sigma_{\omega}$	volatility of DM shock	0.01
$\rho_{\omega}$	autocorrelation of DM shock	0.07

risky assets, we target global banks' average exposure to DM risky assets and the volatility and autocorrelation of the DM risky-asset spread.

One key parameter is the marginal cost of raising equity,  $\phi$ , which, as stressed in the previous section, governs the elasticity of global banks' supply of funds to EMs both in the primary and secondary markets. In turn, this elasticity is directly related to the estimated effect of global banks' net worth on bond prices from Section 2. To calibrate this parameter we simulate various realizations of the returns  $\epsilon(\ell)$  on DM securities for different trading networks in the

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EM debt as a fraction of total assets. We use the spreads on the U.S. High Yield corporate bonds to compute the volatility and autocorrelation of the DM risky asset. See Appendix B for data sources and further details in the computation of moments.

model, standing in an aggregate state that resembles 2008.Q3 in the model.<sup>10</sup> We then compute secondary prices in each trading network and regress the change in those prices on the change in the value of net worth of the banks in each trading network. We calibrate  $\phi$  so that the elasticity in the model regression matches the empirical estimate of 0.15.<sup>11</sup> Further details on the mapping of the model to empirical estimates from the previous section are discussed in Appendix D. Another important parameter is the mass of EM economies,  $\eta_{EM}$ , which directly affects the share of banks' assets invested in EM risky assets.

The calibrated values are shown in Table 3. While in the joint calibration, all moments can be affected by all parameters, we find that the parameters related to EM households mostly affect the EM spread and debt moments, the parameters related to global banks and DM firms affect the price moments of both types of risky assets as well as global banks' portfolio composition. It is also worth noting that, to match EM levels of debt and frequency of default, we obtain a low calibrated value of  $\beta_{EM} = 0.85$ , in line with previous literature on quantitative models of sovereign default. Table 4 shows the data moments and the model moments. All of the moments are fairly well approximated. The average spread in the model is composed of a component due to compensation for default risk and another component from the fact EM borrowing proceeds via financial intermediaries that charge a premium.

## 5.2. *Untargeted Moments*

We evaluate the model's ability to reproduce untargeted moments regarding the synchronization of asset prices, the cross-sectional distribution of spreads and debt, and relevant business cycle moments of EM economies. These exercises help validate the model since matching these data facts was not part of the calibration target, and also shed light into global banks' role in the facts regarding debt prices.

We first ask to what extent is the model able to generate the high synchronization of debt prices within EM economies and with other risky assets. We compute these exercises for the calibration and a for version of the model without global banks. This version of the model corresponds to an economy in which global banks face no financial frictions (i.e.  $\phi = 0$  for equity costs) or, equivalently, to an economy in which there is no financial intermediation and DM households lend directly to EM households. To parametrize this economy, we set the same

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<sup>10</sup>See next section for how we identify the Lehman episode in our model.

<sup>11</sup>Since in the model debt securities are zero-coupon one-year bonds, we use the empirical estimate that uses only bonds with similar maturities around one year. This specification provides a better mapping between data and model. Nevertheless, the point estimate of this specification is similar to the baseline empirical estimate.

TABLE 4. Model Calibration

Target	Data	Model
Debt service	5.7%	8.7%
Average default rate	2.6%	1.9%
Average spread	395bp	323bp
Spreads volatility	170bp	456bp
Correlation of spread and GDP	-31%	-20%
Portfolio weight on DM	90%	90%
Volatility of DM Spread	255bp	105bp
Autocorrelation of DM Spread	0.16	0.03

*Notes:* The first column describes the targeted moments for the model calibration. The second column presents the empirical estimation of the moment. The third column shows the simulated moments from the calibrated model. Debt service is the average annual service of external debt. Yearly default rate is the average of each country's sovereign default frequency in the sample. The time span for average debt, default rate, spread-GDP correlation, average spread, and spread volatility is Sep-96 to Dec-14. The portfolio DM weight comes from the 2017 balance sheets of Citibank, HSBC, JPMorgan, Bank of America, Wells Fargo and Banco Santander. The autocorrelation and volatility of DM Spread were computed from U.S. BB corporate bonds at annual frequency for the period 1997 to 2014. Source: World Bank, St Louis FRED, and banks' balance-sheet statements.

values for the exogenous parameters and recalibrate the remaining parameters to match the same moments as the baseline economy.

We simulate data from both versions of the model and compute the average correlation of individual spreads with the average spread and with required returns from risky DM debt. We compare the model correlations with those of the data. As shown in Table 5, the average correlation of each country's spread with the average EM spread is 69% in the data. In the baseline model economy, this correlation is 77%, while the correlation is 60% in model without global banks. The correlation in the model without global banks is lower than that in the data and in the baseline model since there is zero amplification of the systemic component of output and no transmission from shocks originated in risky DM securities. The baseline model is also able to reproduce a large average correlation between individual EM spreads and the required return on risky DM assets. In particular the average correlation in the data (measured by the

TABLE 5. Comovement in Asset Prices: Model and Data

	Correlation of country spreads with	
	Avg EMs spread	DM risky debt
Data	0.69	0.50
Model	0.77	0.69
No Global Banks	0.60	N.A.

*Notes:* The correlation variable refers to the correlation of each country’s spread with the mean across countries, excluding the treated country. In the data, DM risky debt corresponds to the spread of US High Yield bonds. The *No Global Banks* version excludes financial frictions on global banks, so there is no comovement between emerging-market debt and risky developed-market debt.

correlation between EM spreads and U.S. high-yield spread) is 50% and the one in the model is 69%. In the model without global banks, there is no correlation between these asset prices since there is no transmission of shocks. We also evaluate the model’s ability to reproduce certain moments of the cross-sectional distribution of debt and spreads, namely, the cross-sectional average and standard deviation and their correlation with average aggregate output in the time series. Results, reported in Figure A10, indicate that the model approximates well these moments.

Finally, we also evaluate the model’s ability to reproduce the most salient business cycle moments of the EM economies. In particular, as shown in Figure 6 our model is able to reproduce the high volatility of consumption relative to output, and the high correlation between consumption and output. Additionally, consistent with the data, the model also delivers a countercyclical trade balance, which in the model is due to the fact that interest rates endogenously increase in downturns due to the higher likelihood of default.

## 6. SYSTEMIC DEBT CRISES AND THE ROLE OF GLOBAL BANKS

In this section, we use the calibrated model to quantitatively assess the role of global banks in the transmission and amplification of shocks in the market of EM risky debt. We first analyze the dynamics of spreads during the global financial crisis through the lens of the model and conclude that global banks played an important role transmitting DM shocks. Second, we analyze whether global banks amplify EM-originated systemic shocks.

TABLE 6. Business Cycle Statistics: Model and Data

Target	Data	Model
Consumption volatility / GDP volatility	1.14	1.01
Correlation of consumption and GDP	0.90	0.99
Trade balance volatility	0.04	0.01
Correlation of trade balance and GDP	-0.31	-0.07

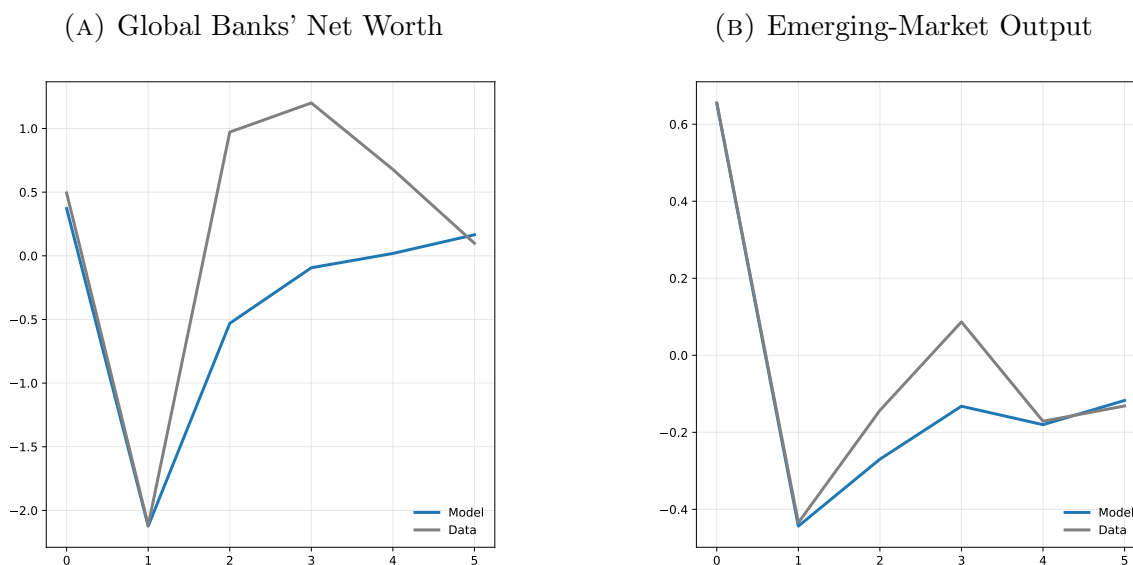
*Notes:* The first row refers to the ratio of the time-series standard deviation of consumption to standard deviation of output. The second row refers to the time-series correlation between consumption and output. The third and fourth row refer to the time-series standard deviation of the trade balance and its correlation with output, respectively. All statistics are averaged across countries in the sample, both in the data and in the model.

### 6.1. EM Spread Dynamics during the Global Financial Crisis

We first use the model to shed light into the dynamics of EM spreads during the global financial crisis. For this, we simulate the model for 1,000,000 periods and identify episodes in which EMs' systemic output fell by the same amount it fell in the data, and in which global banks' aggregate net worth fell as it did in the data. In particular, we look for simulations in which (i)  $y_{EM}$  fell by 4% (the peak-to-trough fall of average EM output during 2007–09), and (ii)  $\omega$  fell such that the net worth of aggregate banks falls as it did in the data. The dynamics of global banks' aggregate net worth and EM output, both in the model and in the data, are shown in Figure 7. While the on-impact effects are targeted, the recovery dynamics emerge endogenously from the model and are roughly consistent with those observed in the data.

We then compare the dynamics of EM spreads from the model-simulated episodes to the observed dynamics of EM spreads during the global financial crisis. The model spreads are computed from debt prices in the primary market; these are the relevant spreads that determine the costs of borrowing for EMs and their consumption dynamics, which we are ultimately interested in. These dynamics are shown in Figure 8. The dynamics of spreads in the model track closely those observed in the data, both in terms of the original spike as well as during the recovery. The model slightly overstates the increase in spreads by predicting an increase of around 650 basis points compared to the observed increase of around 550 basis points. The fact that the model is able to reproduce the dynamics of spreads during the global financial

FIGURE 7. Global Financial Crisis: Exogenous Drivers

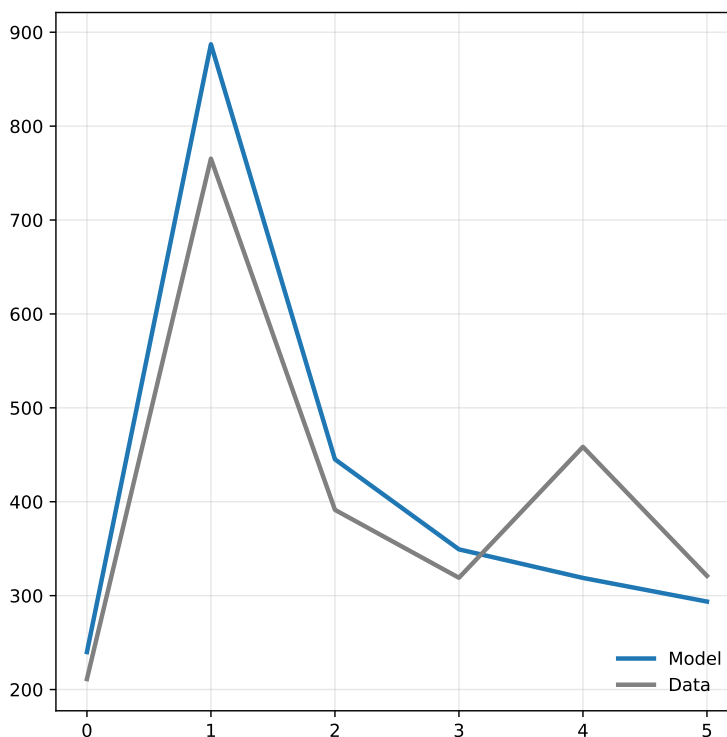


*Notes:* The left panel shows the observed path of global banks' detrended net worth during the global financial crisis and the model-simulated path of the same variable. The right panel shows the observed average detrended EM output during the global financial crisis and the model-simulated path from the same variable. The observed data corresponds to the average of the countries in our sample. The model-simulated data from both panels show the average path of the variables over episodes within the model simulations in which the net worth and the aggregate systemic output fall by an amount in an interval centered on the observed drop in the data. All variables are in percent deviation from a linear trend.

crisis provides an additional source of external validation for the model. In the model, spreads increase due to two forces. First, the lower realizations of returns in DM risky assets has a negative impact on global banks' aggregate net worth. With a lower net worth, global banks must reduce their lending, and thereby reduce their supply of funds to EMs. Given an aggregate EM demand for funds, this reduces bond prices and increases spreads. Second, a drop in EM output increases spreads due to a combination of an increase in default risk and an amplification effect through global banks' net worth.

We then use the model to disentangle the relevance of each of the two shocks in the dynamics of spreads during the global financial crisis. For this, we analyze spread dynamics during episodes in which only  $\omega$  drops and episodes in which only  $y_{EM}$  drops. Results suggest that most of the spread dynamics are due to the DM shock (Figure 9). When we only consider episodes in which returns on DM risky assets fall, the spreads from EMs in the model increase as much as they do in the data. On the other hand, when we consider episodes in which only

FIGURE 8. Emerging-Market Spread Dynamics during the Global Financial Crisis: Model and Data



*Notes:* This figure shows the observed path of emerging-market bond spreads during the global financial crisis and the model-simulated path of the same variable. The observed data is computed as the simple average of spreads of the countries in our sample. The model-simulated data shows the average path of the same variables over episodes within the model simulations in which the net worth and the aggregate systemic output fall by an amount that is in an interval centered on the observed drop in the data. Spreads are annual and are expressed in basis points.

EM output falls, spreads modestly increase by only 100 basis points. This exercise suggests that most of the observed EM-spread dynamics was due to DM shocks and that global banks played a key role in transmitting those shocks, rather than amplifying EM-originated shocks.

### 6.2. Amplification of EM-Originated Shocks

We analyze the effects of EM households' output shocks on debt prices. In particular, we analyze the impulse-response of equal-magnitude negative shocks to the systemic and idiosyncratic components of output.<sup>12</sup> The dynamics of the systemic and idiosyncratic output are

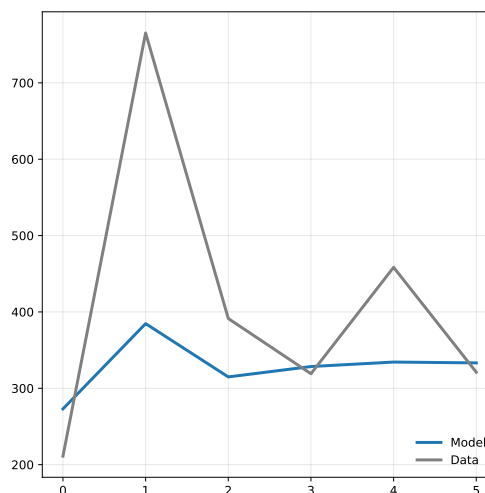
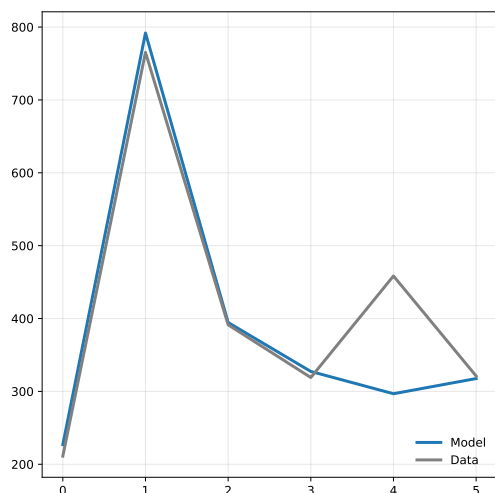
<sup>12</sup>To compute the responses to a shock to the systemic (idiosyncratic) component of output, we simulate the calibrated economies for 1,000,000 periods and identify period in which the systemic (idiosyncratic) component



FIGURE 9. Disentangling Emerging-Market Spread Dynamics

(A) The Role of Shocks in Emerging Markets

(B) The Role of Shocks in Developed Markets



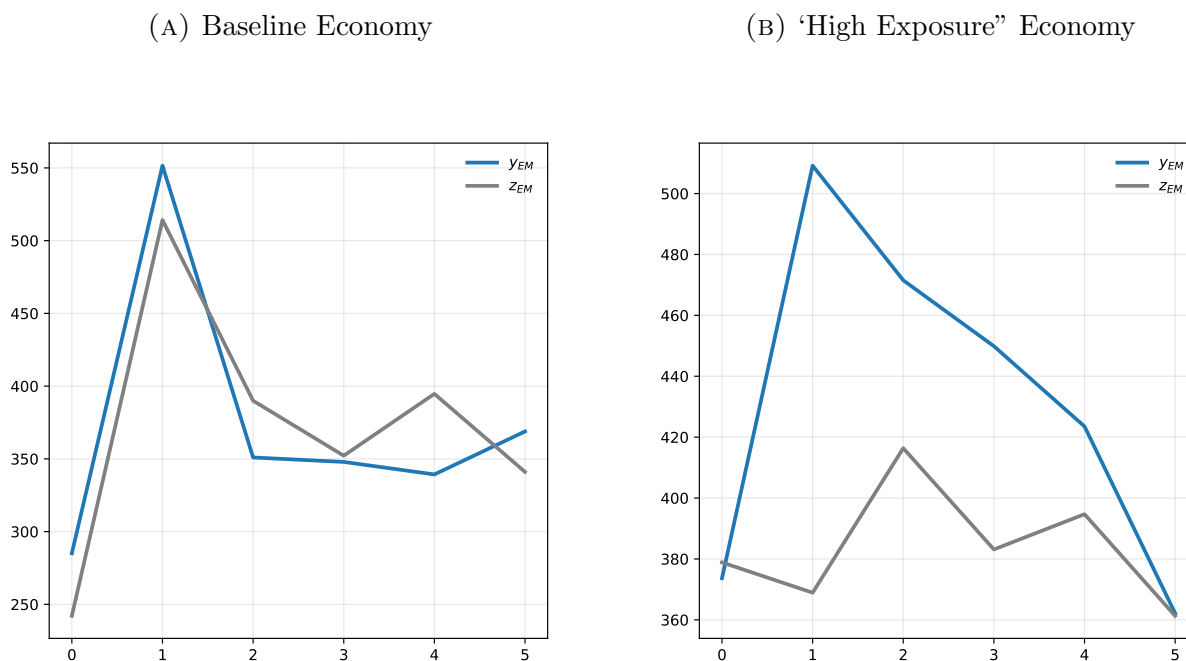
*Notes:* The left panel shows the observed path of emerging-market bond spreads during the global financial crisis and the model-simulated path of the same variable in episodes in which we only condition global banks' net-worth drop to match the data. The observed data is computed as the simple average of spreads of the countries in our sample. The model-simulated data shows the average path of the same variable over episodes within the model simulations in which the net worth falls by an amount that is in an interval centered on the observed drop in the data. The right panel shows observed spreads with the model-simulated path of spreads in episodes in which we only condition emerging markets' aggregate-output drop to match the data. The model-simulated data shows the average path of the spreads over episodes within the model simulations in which the emerging-market average output falls by an amount that is in an interval centered in the observed drop in the data. Spreads are annual and expressed in basis points.

shown in Figure A7. Both negative shocks have the same negative effect on output since they follow the same stochastic process. The dynamics of spreads under both types of shocks and under both calibrations are shown in Figure 10. The left panel shows the spreads' response to an equal-magnitude negative shock to both components of output in the baseline economy. Both shocks trigger an increase in spreads because a lower output increases the value of default relative to the value of repaying and, thus, increases the probability of default. Interestingly, the increase in spreads in response to both shocks is similar in magnitude. This suggests the absence of any global-bank amplification of systemic shocks in the baseline calibration.

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falls by one standard deviation and then trace the dynamics of the variables of interest. We then compute the average response over all identified episodes.

FIGURE 10. Aggregate Response of Spread to Emerging-Market Output Shocks



*Notes:* This figure shows the evolution of spreads in episodes in which the systemic and idiosyncratic components of emerging-market output fall by one standard deviation. The left panel shows the evolution of spreads under the baseline parametrization. The right panel shows a parametrization that exposes global banks to emerging-market debt of 15%. Spreads are measured in basis points.

We then explore the role of global banks’ exposure to EM debt in amplifying systemic output shocks. For this, we consider an alternative calibration in which we recalibrate the value of  $\eta_{EM}$  to obtain an exposure to EM debt of 20%, double the exposure in the baseline and more in line with the observed exposures in the 1980s (see Table A9). In this economy, we compute the same impulse-response exercise as in the baseline economy. Results are shown in the right panel of Figure 10. In this economy, a negative shock to output can have a differential effect on spreads depending on the nature of the shock. A one-standard-deviation negative shock to the idiosyncratic component of output triggers an increase in the spreads of that country of approximately 50bps. In contrast, a negative shock of the same magnitude to the systemic component of output triggers a spread increase that is three times as large as the response to the idiosyncratic shock. We argue next that this differential response is due to the amplification effect that systemic shocks create by affecting global banks’ balance sheets.

## 7. CONCLUSION

We show that global banks play an important role in the configuration of EMs' systemic debt crises. Using bond-level data on prices and holdings by global banks, we first document that bond prices react to shocks to the net worth of the holder's of these bonds.

Based on this observation, we develop a dynamic world-economy model in which external borrowing is intermediated by global banks. We use our empirical estimates to infer the degree of financial frictions that banks face. We find that banks are relevant in the generation and amplification of systemic debt crises. The nature of the global banks' role in systemic debt crises is governed by their exposure to EM debt. When banks are highly exposed, they amplify systemic EM shocks, whereas when their exposure is low, they transmit shocks from other risky assets to the EM debt market. Our model thus formalizes an long-held view in policy circles whereby banks are relevant actors shaping global EM crises. It also sheds light into the channels through which they operate.

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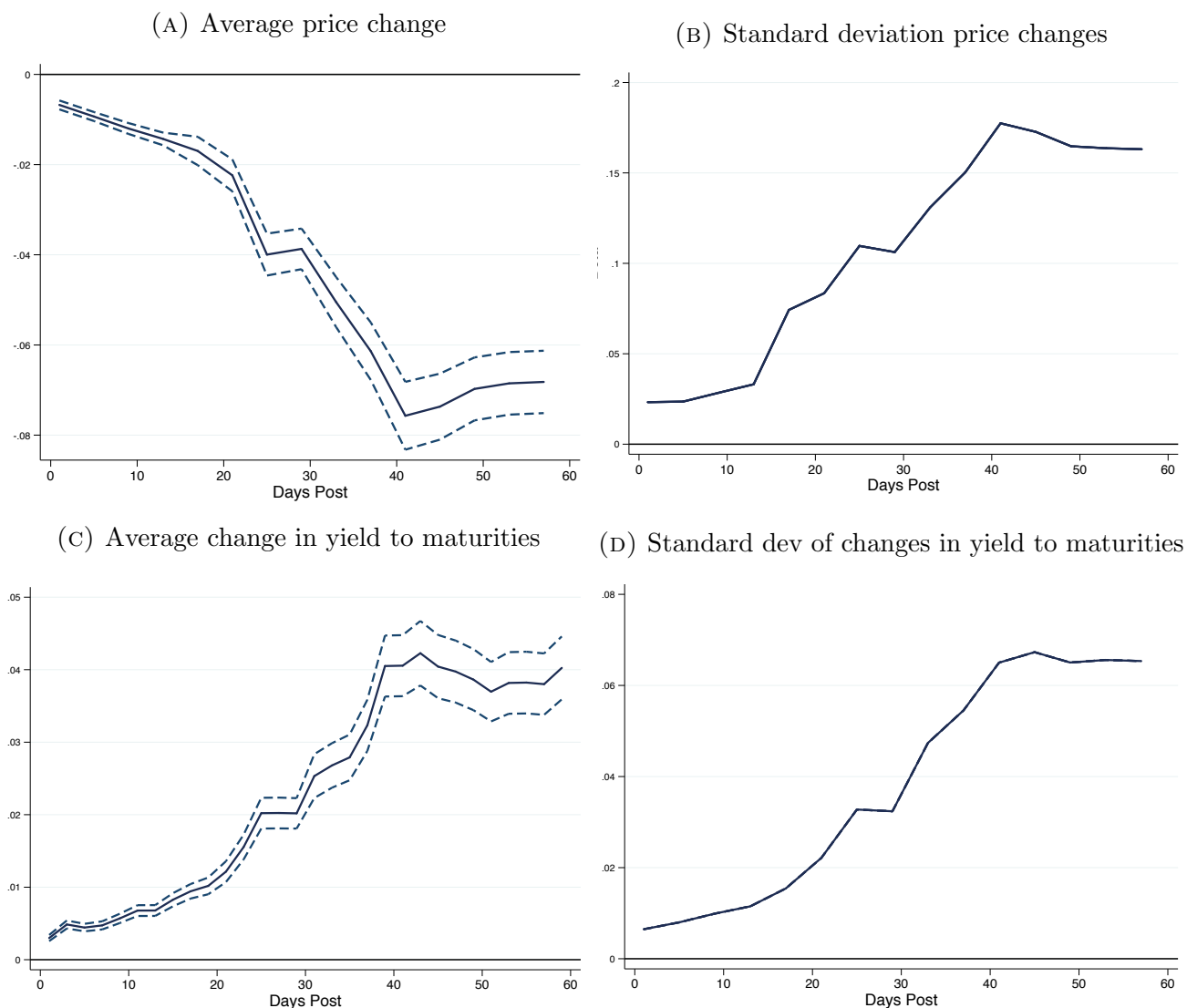
## APPENDIX A. ADDITIONAL FIGURES AND TABLES

TABLE A1. Descriptive Statistics by Country

Country	N Bonds	YTM	Maturity	Bid-Ask Spread
Argentina	42	13.6%	234	0.81%
Bulgaria	2	5.7%	1768	0.22%
Brazil	65	8.2%	593	0.43%
Chile	26	5.2%	208	0.52%
China	11	4.3%	139	0.34%
Colombia	21	6.7%	262	0.43%
Croatia	8	5.5%	435	0.47%
Indonesia	15	7.0%	487	0.34%
Jamaica	7	8.4%	735	0.77%
Lithuania	5	6.9%	548	0.31%
Latvia	2	8.2%	1522	0.54%
Mexico	62	7.0%	68	0.48%
Malaysia	24	4.3%	189	0.38%
Panama	17	5.1%	569	0.63%
Peru	11	5.8%	648	0.43%
Philippines	23	6.0%	252	0.41%
Pakistan	4	13.7%	1218	0.66%
Poland	17	4.3%	92	0.30%
Russia	6	6.3%	1299	0.18%
El Salvador	4	6.5%	2095	0.44%
Thailand	11	8.6%	26	0.52%
Turkey	19	6.4%	296	0.33%
Ukraine	11	9.6%	294	0.31%
Venezuela	15	11.7%	416	0.47%
South Africa	18	8.1%	242	0.37%
Average	18	7.3%	586	0.44%

*Notes:* This table shows descriptive statistics by country of the EM bonds included in the empirical analysis of Section 2. *N Bonds* refers to the number of bonds available per country. *YTM* refers to the average yield to maturity of bonds of a given country, in percent. *Maturity* refers to the average residual maturity in days. *Bid-Ask Spread* expressed in percent. All average variables are computed using their values before the Lehman episode (10 days before September 15 2008).

FIGURE A1. Emerging-Market Bond Prices Following the Lehman Episode



*Notes:* Panel (A) shows the average cumulative daily change in log prices of EM bonds after the Lehman bankruptcy episode. Panel (B) shows the standard deviation of the cumulative daily change in log prices of EM bonds after the Lehman bankruptcy episode across bonds. Panel (C) shows the average cumulative daily change in log gross yield to maturities of EM bonds after the Lehman bankruptcy episode. Panel (D) shows the standard deviation of the cumulative daily change in log gross yield to maturities of EM bonds after the Lehman bankruptcy episode across bonds. For details on the data, see Section 2.



TABLE A2. Global Banks Included in the Empirical Analysis

Aegon NV	Hartford	Royal Bank of Scotland
Allianz SE	HSBC	Societe Generale
American International Group	Intesa Sanpaolo SpA	Sovereign Bank
Ameriprise Financial Inc	JPMorgan	Suntrust Banks
BNP Paribas	Keycorp	SVB
BNYM	Lehman Brothers	T Rowe Price Group Inc
Bank of America	M&T Bank	TD Bank
Bank of Nova Scotia	Merrill Lynch	U.S. Bancorp
Barclays Bank	MetLife Inc	UBS
Bb&T	Mitsubishi UFJ	Unionbancal
BlackRock Inc	Morgan Stanley	Wachovia
CIBC	NN Group NV	Wells Fargo
CIT	National City	
Citigroup	Nikko Asset Management Co Ltd	
Comerica Corporation	PNC	
Credit Suisse	Principal Financial Group Inc	
Deutsche Bank	Prudential Financial Inc	
Fifth Third Bancorp	Regions	
GE Capital	Royal Bank of Canada	

TABLE A3. Descriptive Statistics by Financial Institution

GFI	N Bonds	N Countries	Avg Share	$\Delta n_i$
Prudential Financial Inc	367	23	3.77%	0.064
Allianz SE	265	25	10.36%	-0.117
JPMorgan	230	20	1.91%	0.01
MetLife Inc	197	21	7.87%	0.13
BNYM	187	23	2.54%	-0.140
BlackRock Inc	184	22	3.27%	-0.017
Deutsche Bank	178	23	5.42%	-0.07
UBS	173	23	11.82%	-0.330
Intesa Sanpaolo SpA	171	21	1.49%	-0.043
American International Group	163	20	1.96%	-2.116
Hartford	161	21	3.05%	-0.077
Ameriprise Financial Inc	155	22	6.96%	-0.114
BNP Paribas	151	24	1.88%	-0.034
Goldman Sachs	140	21	3.18%	-0.413
Wells Fargo	135	19	0.82%	0.170
NN Group NV	124	21	15.24%	0.00
Aegon NV	122	20	1.77%	-0.233
HSBC	110	21	4.75%	-0.017
Nikko Asset Management Co Ltd	107	16	2.85%	-0.079
T Rowe Price Group Inc	103	20	6.19%	0.015
Average	171	21	4.86%	-0.17

*Notes:* This table shows descriptive statistics of the twenty financial institutions included in the empirical analysis of Section 2 holding a largest number of EM bonds. *N Bonds* refers to the number of bonds in our sample held by each of these financial institutions, and *N Countries* to the number of different countries included in these bonds. *Avg Share* denotes a bank's average share of reported holdings of a particular bond before the Lehman episode (2008.q2).  $\Delta n_i$  denotes the change in the log stock price of each financial institution in the narrow window around the Lehman episode (10 days before September 15 2008 and 3 days after).

TABLE A4. Shares by Sector of Bonds Included in the Empirical Analysis

	Share
Government	0.53
Industrial	0.05
Financial	0.12
Utilities	0.06
Communication	0.06
Energy	0.05
Other	0.12

*Notes:* This table shows the average share of bonds by sector included in the empirical analysis of Section 2. Other includes: consumer (68 percent), Basic material (35 percent), Diversified (7 percent), and Technology (0.5 percent). Source of data and sectors definition: Bloomberg.

TABLE A5. The Effect of Global Banks' Net Worth on Emerging-Market Bond Yields

Horizon (Days)	(1) Baseline	(2) Only Sovereign	(3) Additional Controls	(4) Same Maturity
1	-0.007** [0.002]	-0.019 [0.013]	-0.008 [0.005]	-0.009 [0.006]
20	-0.016* [0.009]	-0.04* [0.023]	-0.021* [0.012]	-0.017 [0.013]
40	-0.088** [0.037]	-0.097 [0.086]	-0.11* [0.062]	-0.070 [0.071]
60	-0.048 [0.036]	-0.084 [0.054]	-0.056** [0.028]	-0.067* [0.041]
N obs	418	125	359	118

*Notes:* This table shows the results from estimating (1) with the change in the log gross yield to maturity as the left-hand-side variable, under different specifications and for different time horizons ( $h$ ). Column (1) shows the results for our baseline specification. Column (2) shows the results for the specification only including sovereign bonds. Column (3) shows the results for the specification with additional controls (bond's maturity, bid-ask spread, amount, and initial yield to maturity). Column (4) shows the result only using bonds with similar maturity (half to two years).

TABLE A6. The Effect of Global Banks' Net Worth on Emerging-Market Bond Prices

Horizon (Days)	(1) Baseline	(2) Only Sovereign	(3) Additional Controls	(4) Same Maturity
1	0.011 [0.012]	0.034 [0.057]	0.011 [0.009]	0.034 [0.044]
20	0.038 [0.024]	0.266 [0.168]	0.051* [0.029]	0.085 [0.105]
40	0.186** [0.089]	0.773* [0.446]	0.242** [0.095]	0.2010 [0.264]
60	0.137** [0.067]	0.698* [0.409]	0.158* [0.091]	0.212 [0.221]
N obs	418	125	359	118

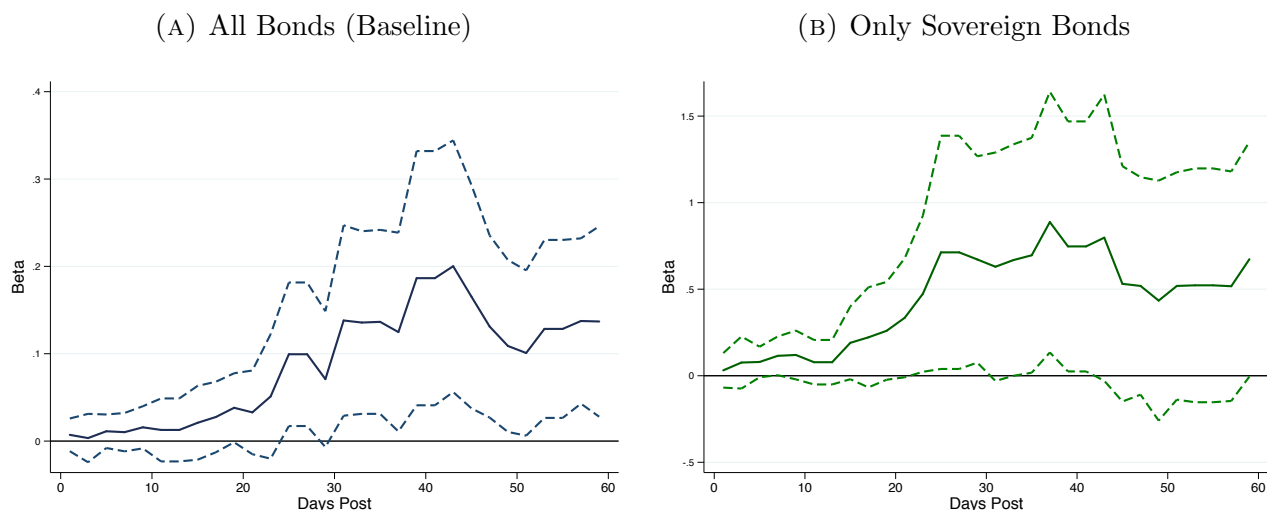
*Notes:* This table shows the results from estimating (1) with the change in the log bond price as the left-hand-side variable, under different specifications and for different time horizons ( $h$ ). Column (1) shows the results for our baseline specification. Column (2) shows the results for the specification only including sovereign bonds. Column (3) shows the results for the specification with additional controls (bond's maturity, bid-ask spread, amount, and initial yield to maturity). Column (4) shows the result only using bonds with similar maturity (half to two years).

TABLE A7. Emerging-Market Bonds' Characteristics and Holders' Change in Net Worth

	$\beta_n$
Residual maturity	-267 [296]
Bid-ask spread	0.16 [0.21]
Amount issued	-5091 [10537]
Amount outstanding	-5452 [10508]

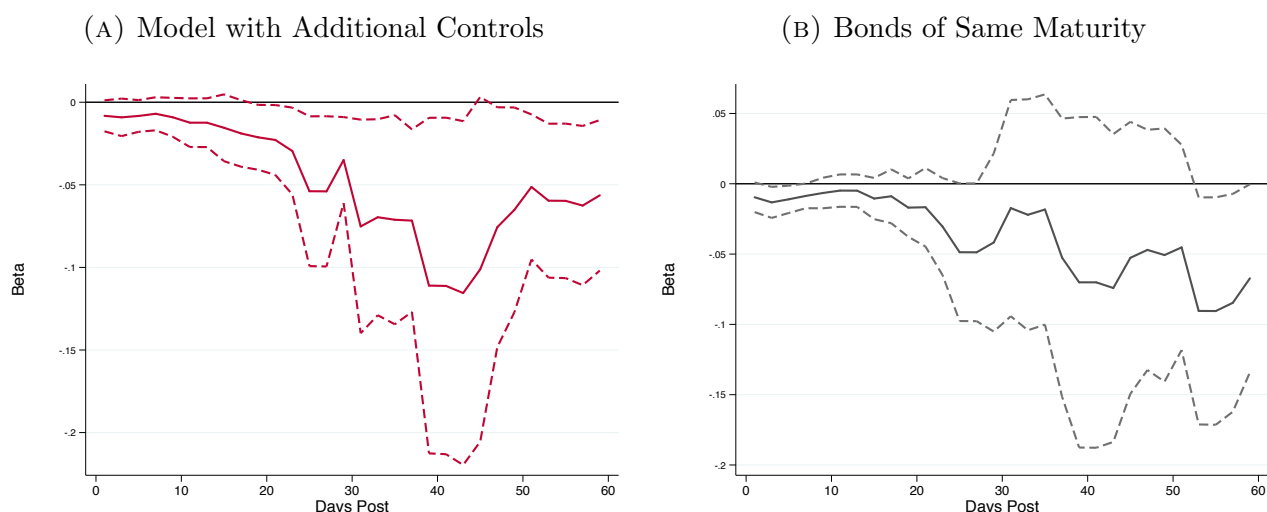
*Notes:* This table shows the estimated coefficient  $\beta_n$  from the regression relating bond-level characteristics and changes in the holder's net worth during the Lehman episode  $X_{iks} = \alpha_{ks} + \beta_n \Delta n_i + \varepsilon_i$ , where denote  $X_{iks}$  denotes the maturity (measured in days), bid-ask spread (in percent), and amount issued and outstanding, measured in millions of dollars, or bond  $i$ , issued by country  $k$ , sector  $s$  and  $\Delta n_i$  the average net worth contraction of global banks holding bond  $i$ . Standard errors are in brackets.

FIGURE A2. The Effect of Global Banks' Net Worth on Emerging-Market Bond Prices



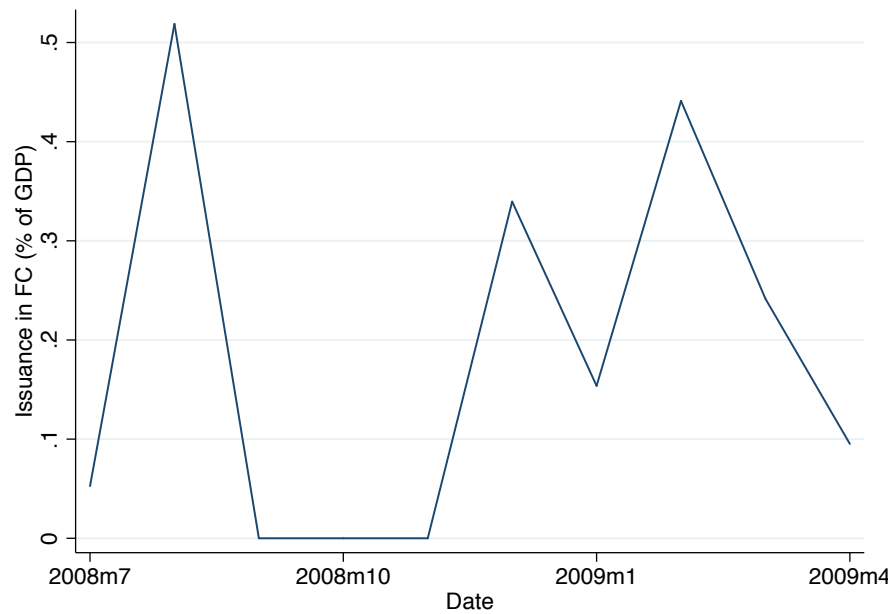
Notes: Panel (A) shows the estimated elasticity of bond prices,  $\beta_h$ , to changes in the holder's net worth at horizon  $h$  from estimating the regression 1. Solid lines represent the point estimates of the regression at each horizon, and dotted lines are the 90%-confidence intervals. Panel (B) shows the estimated coefficient in which 1 is estimated using only sovereign bonds.

FIGURE A3. The Effect of Global Banks' Net Worth on EM Bond Yields: Additional Specifications



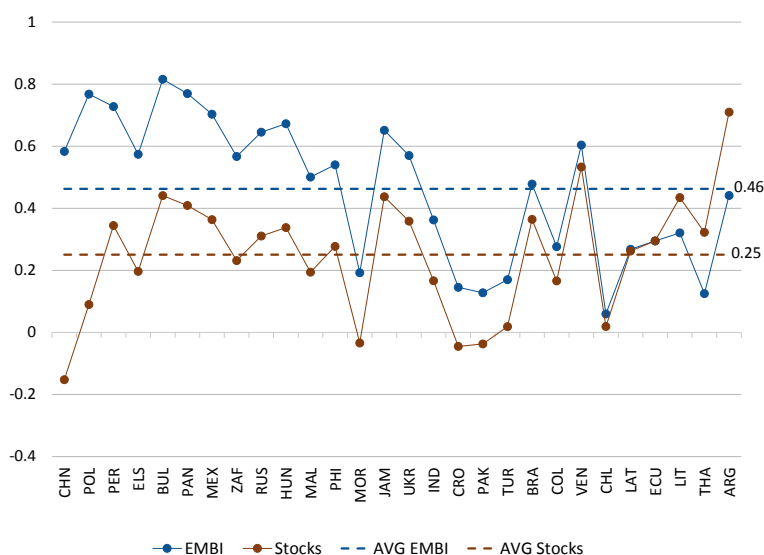
Notes: Panel (A) shows the estimated elasticity of bond yields,  $\beta_h$ , to changes in the holder's net worth at horizon  $h$  from estimating a version of model 1 that includes maturity, bid-ask spread, amount issued, amount outstanding, and pre-Lehman yield-to-maturity as controls. Panel (B) shows the estimated coefficient in version of model 1 that only includes bonds with maturities between half and two years.

FIGURE A4. Emerging-Market Debt Issuance during the Lehman Episode



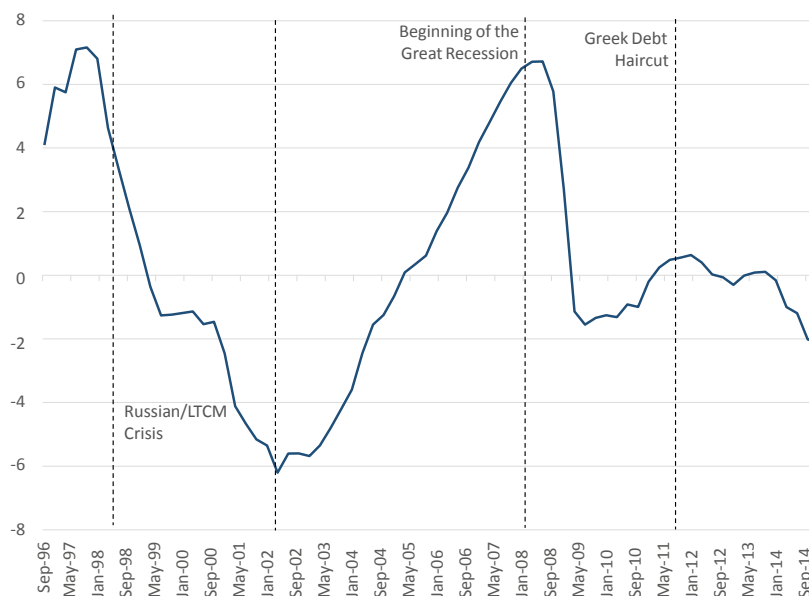
*Notes:* This figure shows the total amount of new sovereign debt issuance in foreign currency by emerging-market economies during the Lehman episode. Issuance is expressed as a function of GDP and averaged across countries.

FIGURE A5. Return Comovements within Emerging Markets and with U.S. Stocks



Notes: This figure shows the empirical correlation between a country’s sovereign-bond total return and the total return of the U.S. stock market and the simple average of all other countries’ sovereign-bond total returns. We take the S&P500 to represent the U.S. stock market, and the EMBI for the countries sovereign-bond total return.

FIGURE A6. Systemic Component of Emerging Markets’ Output



Notes: This figure shows the systemic component of output, defined as the simple average output of all countries in our sample. Output was log-linearly detrended.



TABLE A8. Major Global Banks' Balance Sheets: 2017

Bank	Share Sovereign Non-U.S. Debt	Share EM Debt	Ratio Equity to Assets
Santander	25.5%	41%	7.4%
HSBC	24.9%	91.2%	7.8%
Citi	21.1%		10.9%
JPMorgan	12.6%		10.1%
BOFA	5.2%		11.7%
Wells Fargo	2%	61%	10.7%
Average	15.2%	48.3%	9.8%

*Notes:* This table shows selected items of major banks' balance sheets for 2017. The first column shows the share of banks' claims on non-U.S. sovereigns over risky assets. The second column shows what fraction of those claims are on emerging markets. The last column shows the equity-to-assets ratio of each bank. The last row represents the simple average of each variable. Data is publicly available.

TABLE A9. Major Global Banks' Balance Sheets: 1980s

	1982	1984	1986
<i>Debt-to-Capital</i>			
All Banks	186.5%	156.6%	94.8%
Top 9	287.7%	246.3%	153.9%
<i>Capital-to-Assets</i>			
	4.8%	6.1%	7.1%
<i>Debt-to-Assets</i>			
All Banks	9.0%	9.6%	6.7%
Top 9	13.8%	15.0%	10.9%

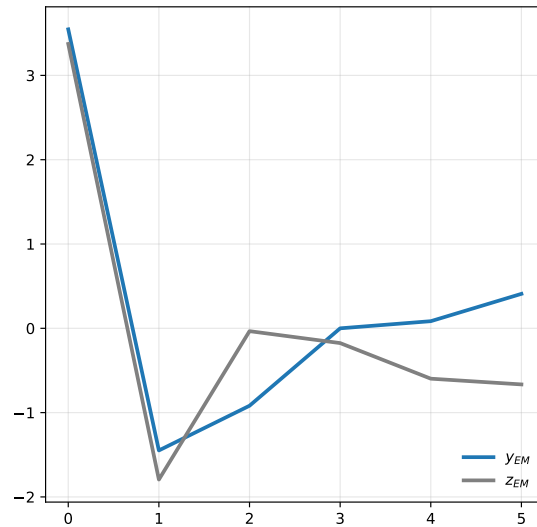
*Notes:* This table shows selected items of U.S. commercial banks' balance sheets from the 1980s. Debt-to-Capital refers to the ratio of banks' claims on developing countries to banks' primary capital. The Capital-to-Assets variable is the banks' ratio of primary capital to total assets. These two variables are simple averages across banks. Debt-to-Assets is computed as Debt-to-Capital times Capital-to-Assets, and it represents the ratio of banks' claims on developing countries to banks' total assets. The top nine banks refers to the top nine largest U.S. banks during the 1980s. Source: [Sachs \(1989\)](#)

TABLE A10. Additional Debt and Spreads Moments

Target	Data	Model
Cross sectional SD		
Debt-to-GDP	0.097	0.012
Spreads (bps)	303.1	56.4
Time series		
Correlation Average Debt and GDP	-0.098	-0.94
Correlation Average Spreads and GDP	-0.355	-0.086
Correlation SD Debt and GDP	0.083	0.38
Correlation SD Spreads and GDP	-0.475	-0.174

*Notes:* The first two rows refer to the cross-sectional debt service and spreads. The time series statistics are computed as the average cross-country time series statistic. For the model we simulate the same number of countries as in the data.

FIGURE A7. Systemic and Idiosyncratic Output Shocks in the Model



*Notes:* This figure shows the evolution of the systemic and aggregate components of emerging-market output in model-simulated data. The model-simulated data shows the average path of the variables over episodes within which the variables fall by one standard deviation. Both variables are expressed in percent deviations from a linear trend.

## APPENDIX B. DATA APPENDIX

B.1. *Sample of Countries*

Our sample of countries consists of emerging economies with sufficient data available to conduct our empirical analysis of Section 2, using bond-level data, and our quantitative analysis in Section 5, using aggregate data. In particular, we consider those countries that: (i) Are part of JPMorgan's EMBI, (ii) have outstanding bonds issued before 2008 and maturing after 2010 with daily data, and (iii) have at least 10 years of available data on aggregate debt prices and output (detailed in the subsection B.2). Twenty-eight countries met the sample criteria: Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Indonesia, Jamaica, Lithuania, Latvia, Mexico, Malaysia, Panama, Peru, Philippines, Pakistan, Poland, Russia, El Salvador, Thailand, Turkey, Ukraine, Venezuela, South Africa.

B.2. *Aggregate Data on Debt Prices and Fundamentals*

For all countries in the sample, we collect data on prices of sovereign debt and on output. Debt-price data consists of data on sovereign spreads of a synthetic basket of bonds of each country, computed by the EMBI. A bond spread is the excess yield of the bond over the yield of a risk-free zero-coupon bond (i.e., a US Treasury) of the same maturity. A country's spread is a synthetic measure of the spreads of a representative basket of bonds issued by that country. It measures the implicit interest rate premium required by investors to be willing to invest in a defaultable bond of that particular country. Spread data were obtained from Datastream. Data on real GDP at a quarterly frequency was obtained from national sources and the IMF. The sample period ranges from 1994 to 2014. However, data on particular countries may start later or end earlier, depending on their data availability.

## APPENDIX C. RECURSIVE MODEL REPRESENTATION

This section provides a recursive representation of the model of the global economy developed in Section 3. Within each period, the timing is as follows.

- i. At the beginning of each period, the exogenous aggregate state,  $\mathbf{s}_x \equiv \{y_{EM}, \omega\}$ , and the exogenous idiosyncratic states,  $(z_i, \zeta_i)_{i \in [0,1]}$  and  $(\epsilon_\ell)_{\ell \in [0,1]}$ , are realized.
- ii. *Secondary Market.* Global banks repay their outstanding deposits. Banks issue new deposits, raise equity and trade risky securities in the secondary market. DM households choose their savings. The aggregate state is given by  $\mathbf{s} \equiv \{\mathbf{s}_x, \Delta\}$ , where  $\Delta \equiv \{A_{DM}, D, g(b, z)\}$ ,

and  $g(b, z)$  is the joint distribution of debt and idiosyncratic output at the repayment stage of EM economies that borrowed in the previous period.

- iii. *Primary Market.* EM households choose their repayment and DM nonfinancial firms produce output. A random fraction  $(1 - \sigma)$  of global banks exit, and a new mass of banks enter the economy. Global banks choose their portfolios and issue equity, nonfinancial firms their investment, and EM households their borrowing.

*Global Banks' Recursive Problem.* Let  $n$  be the idiosyncratic net worth of a global bank at in the secondary market. Then the value of an individual bank in the secondary market stage in a trading network with realized quality of capital shock  $\epsilon$  is given by

$$\tilde{v}(n, \epsilon, \mathbf{s}) = \max_{\substack{\{\tilde{a}_{EM,(b,z)} \geq 0\}, \\ \tilde{a}_{DM} \geq 0, d, \tilde{div}}} \tilde{div}(1 + \mathbb{I}_{\tilde{div} < 0} \mathcal{C}(\tilde{div}, n)) + v(x, d, \mathbf{s}) \quad (25)$$

subject to

$$\begin{aligned} & \int \int_{(b,z):g(b,z)>0} q_{EM,(b,z)}(\mathbf{s}, \epsilon) \tilde{a}_{EM,(b,z)} db dz + q_{DM}(\mathbf{s}, \epsilon) \tilde{a}_{DM} + \tilde{div} = n + d, \\ & d \leq \kappa x \\ & x = \int \int_{(b,z):g(b,z)>0} \hat{\iota}_{EM,(b,z)}(\mathbf{s}) a_{EM,(b,z)} db dz + \omega \epsilon \left( \alpha \hat{A}_{DM}^{\alpha-1} + 1 - \delta \right) a_{DM}. \end{aligned}$$

where  $d$  denotes the choice of deposits,  $\tilde{div}$  denotes dividend payments,  $\tilde{a}_{EM,(b,z)}$  denotes the mass of securities from economies with borrowing  $b$  and idiosyncratic income  $z$ ,  $\tilde{a}_{DM}$  the mass of securities from non-financial firms from DM economies purchased, and  $q_{EM,(b,z)}(\mathbf{s}, \epsilon)$ ,  $q_{DM}(\mathbf{s}, \epsilon)$  their respective secondary market prices, and  $\iota(\cdot)$  and  $\hat{A}_{DM}(\cdot)$  denotes the perceived policies for aggregate DM assets at the secondary market stage. Note that this formulation uses the equilibrium deposit rate obtained from the DM households' problem,  $R_{dt} = \beta_{DM}^{-1}$  and the return on DM investment,  $\omega \epsilon \left( \alpha \hat{A}_{DM}^{\alpha-1} + 1 - \delta \right)$ , that incorporates nonfinancial DM firms' optimal choices. The value at the primary market,  $v(x, d, \mathbf{s})$ , depends on the cash on hand and the level of deposits and is given by

$$v(x, d, \mathbf{s}) = \max_{\substack{\{a'_{EM,(b,z)} \geq 0\}, \\ a'_{DM} \geq 0, div}} (1 - \sigma)(x - d) + \sigma (div(1 + \mathbb{I}_{div < 0} \mathcal{C}(div, n)) + \beta_{DM} \mathbb{E} [\tilde{v}(n', \epsilon', \mathbf{s}')]]) \quad (26)$$

subject to

$$\int \int_{(b,z):g_+(b,z)>0} q_{EM,(b,z)}(\mathbf{s}) a'_{EM,(b,z)} dbdz + q_{DM}(\mathbf{s}) a'_{DM} = x - div, \quad (27)$$

$$n = x - d \quad (28)$$

$$n' = \int \int_{(b,z):g_+(b,z)>0} q_{EM,(b,z)}(\mathbf{s}', \epsilon') a'_{EM,(b,z)} dbdz + q_{DM}(\mathbf{s}', \epsilon') a'_{DM} - R_d d, \quad (29)$$

$$\mathbf{s}' = \Gamma(\mathbf{s}, \mathbf{s}'_x, \hat{A}_{DM}(\mathbf{s}), \hat{D}(\mathbf{s}), \hat{b}'(b, \hat{z}, \mathbf{s})) \quad (30)$$

where  $div$  denotes dividend payments from banks that did not exit,  $a'_{EM}(b, z)$  denotes the mass of securities purchased from a economies with borrowing  $b$  and idiosyncratic income  $z$ ,  $a'_{DM}$  the mass of securities purchased from non-financial firms from DM economies, and  $q_{EM,(b,z)}(\mathbf{s}), q_{DM}(\mathbf{s})$  their respective primary market prices.<sup>13</sup> The law of motion of the aggregate state,  $\mathbf{s}'$  is given by  $\mathbf{s}' = \Gamma(\mathbf{s}, \mathbf{s}'_x, \hat{A}_{DM}(\mathbf{s}), \hat{D}(\mathbf{s}), \hat{b}'(b, z, \mathbf{s}))$ , and  $\hat{A}_{DM}(\cdot), \hat{D}(\cdot)$ , and  $\hat{b}'(\cdot)$  denote perceived policies at the borrowing stage describing, respectively, aggregate DM assets, deposits, and EM borrowing. The law of motion and perceived policies are equilibrium objects in the model, taken as given by global banks and EM borrowers.

*EMs' Recursive Problem.* The borrower's repayment decision is characterized by the following problem

$$V(b, z, \mathbf{s}) = \max_{\iota} \iota V^r(b, z, \mathbf{s}) + (1 - \iota) V^d(z, \mathbf{s}), \quad (31)$$

where  $V^r(b, z, \mathbf{s})$  and  $V^d(z, \mathbf{s})$  denote, respectively, the values of repayment and default, described below.

The borrower's debt-issuance decision is characterized by the problem

$$V^r(b, z, \mathbf{s}) = \max_{b'} u(c) + \beta \mathbb{E} [V(b', z', \mathbf{s}')] \quad (32)$$

$$\text{s.t. } c = y_{EM} + z + q(b', z, \mathbf{s}) b' - b, \quad (33)$$

$$\mathbf{s}' = \Gamma(\mathbf{s}, \mathbf{s}'_x, \tilde{A}_{DM}(\mathbf{s}), \hat{D}(\mathbf{s}), \hat{b}'(b, z, \mathbf{s})).$$

Finally, the value of default is given by

$$V^d(z, \mathbf{s}) = \max_{b'} u(c) + \beta \mathbb{E} [\phi V^r(0, z', \mathbf{s}') + (1 - \phi) V^d(z', \mathbf{s}')] \quad (34)$$

$$\text{s.t. } c = \mathcal{H}(y_{EM} + z),$$

$$\mathbf{s}' = \Gamma(\mathbf{s}, \mathbf{s}'_x, \tilde{A}_{DM}(\mathbf{s}), \hat{D}(\mathbf{s}), \hat{b}'(b, z, \mathbf{s})).$$

---

<sup>13</sup>Note that we adopt the notation of  $q_{EM,(b,z)}(\mathbf{s})$  for primary market prices of EM bonds and  $q_{EM,(b,z)}(\mathbf{s}, \epsilon)$  for secondary market prices, and a similar notation for DM assets.

*Equilibrium Definition.* We can now define a recursive equilibrium.

**DEFINITION 2.** *A recursive equilibrium consists of global banks' policies in the secondary market stage,  $\{\tilde{a}_{EM(b,z)}(n, \epsilon, \mathbf{s}), \tilde{a}_{DM}(n, \epsilon, \mathbf{s}), d(n, \epsilon, \mathbf{s})\}$ , policies in the primary market stage  $\{a'_{EM(b,z)}(x, d, \mathbf{s}), a'_{DM}(x, d, \mathbf{s}), div_{DM}(x, d, \mathbf{s})\}$ , and value functions,  $\tilde{v}(n, \epsilon, \mathbf{s})$  and  $v(x, d, \mathbf{s})$ ; borrowers' policies,  $\{\iota(b, z, \mathbf{s}'), b'(b, z, \mathbf{s})\}$ , and value functions,  $\{V(b, z, \mathbf{s}), V^r(b, z, \mathbf{s}), V^d(z, \mathbf{s})\}$ ; secondary market prices  $q_{EM,(b,z)}(\mathbf{s}, \epsilon)$ ,  $q_{DM}(\mathbf{s}, \epsilon)$  and primary market price schedules,  $q(b', z, \mathbf{s})$ ; law of motion of the aggregate state,  $\Gamma(\mathbf{s}, \mathbf{s}', \tilde{A}'_{DM}(\mathbf{s}), \tilde{D}'(\mathbf{s}), \tilde{b}'(b, z, \mathbf{s}))$ ; and perceived policies,  $\{\tilde{\iota}(b, z, \mathbf{s}), \tilde{b}'(b, z, \mathbf{s}), \tilde{A}'_{DM}(\mathbf{s}), \tilde{D}'(\mathbf{s})\}$  such that*

- (1) *Given prices, laws of motion, and perceived policies, global banks' policies and value function solve their recursive problem (25)–(26).*
- (2) *Given prices, laws of motion, and perceived policies, borrowers' policies and value functions solve their recursive problem (31)–(34).*
- (3) *Asset markets clear.*
- (4) *The laws of motion of the aggregate state are consistent with individual policies.*
- (5) *Perceived policies coincide with optimal policies.*

*Equilibrium Characterization.* The following proposition characterizes the optimal choices of global banks.

**PROPOSITION 1.** *Any equilibrium with positive aggregate holdings of all risky assets must have:*

$$\mathbb{E} \left[ \tilde{\nu}(\mathbf{s}', \epsilon') \frac{q_{EM,(b,z)}(\mathbf{s}', \epsilon')}{q_{EM,(b,z)}(\mathbf{s})} \right] = \mathbb{E} \left[ \tilde{\nu}(\mathbf{s}', \epsilon) \frac{q_{DM}(\mathbf{s}', \epsilon)}{q_{DM}(\mathbf{s})} \right]$$

$$\frac{\iota_{EM,(b,z)}(\mathbf{s})}{q_{EM,(b,z)}(\mathbf{s}, \epsilon)} = \frac{\omega \epsilon (\alpha A_{DM}^{\alpha-1} + 1 - \delta)}{q_{DM}(\mathbf{s}, \epsilon)}.$$

*Additionally, the value functions of global banks are linear in their idiosyncratic states:*

$$\tilde{v}(n, \epsilon, \mathbf{s}) = \tilde{\nu}(\epsilon, \mathbf{s})n \tag{35}$$

$$v(x, d, \mathbf{s}) = \nu_x(\mathbf{s}) + \nu_d(\mathbf{s}) \tag{36}$$

where the marginal value of net worth, cash on hand and deposits solve the following recursive equations:

$$\begin{aligned}\tilde{v}(\mathbf{s}, \epsilon) &= \left( (1 - \sigma) + \sigma \left( \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \tilde{\nu}(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 + \beta_{DM} \left( \mathbb{E} \left[ \tilde{\nu}(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - \kappa \mathbb{E} [\tilde{\nu}(\mathbf{s}', \epsilon')] R_d \right) \right) \right) \\ &\quad \frac{1}{\left( \frac{q_{DM}(\mathbf{s}, \epsilon)}{\omega \epsilon (\alpha A_{DM}^{\alpha-1} + 1 - \delta)} - \kappa \right)} \\ \nu_x(\mathbf{s}) &= (1 - \sigma) + \sigma \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \tilde{\nu}(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 + \beta_{DM} \mathbb{E} \left[ \tilde{\nu}(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] \right) \\ \nu_d(\mathbf{s}) &= (1 - \sigma) + \sigma \beta_{DM} \mathbb{E} [\tilde{\nu}(\mathbf{s}', \epsilon')] R_d\end{aligned}$$

*Proof.* We proceed by guessing linearity of the value function and verifying the conjecture. Conjecture first linearity of the first stage problem:  $v(\mathbf{s}, n) = \nu(\mathbf{s})n$  and solve the problem of the primary market. Substituting the conjectured functional form and solving the optimal portfolio problem yields the following optimality condition:

$$\mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{EM,(b,z)}(\mathbf{s}', \epsilon')}{q_{EM,(b,z)}(\mathbf{s})} \right] = \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] \quad (37)$$

for any risky asset with positive holdings in the primary market. Substituting (27), (29) and (37) into (26) yields the following problem:

$$\begin{aligned}v(\mathbf{s}, x, d) &= \max_{div} (1 - \sigma)(x - d) + \sigma div (1 + \mathbb{I}_{div < 0} \mathcal{C}(div, x - d)) \\ &\quad + \sigma \beta_{DM} \left( \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] (x - div) - \mathbb{E} [\nu(\mathbf{s}', \epsilon')] R_d d \right)\end{aligned}$$

Conjecturing that in equilibrium  $div < 0$  and taking first order condition with respect to  $div$  yields the following optimal dividends

$$-div = \frac{1}{2\phi} \left( \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}')}{q_{DM}(\mathbf{s})} \right] - 1 \right) (x - d) \quad (38)$$

Substituting back into the value function:

$$\begin{aligned}v(\mathbf{s}, x, d) &= (1 - \sigma)(x - d) \\ &\quad + \sigma \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 (x - d) + \beta_{DM} \left( \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] x - \mathbb{E} [\nu(\mathbf{s}', \epsilon')] R_d d \right) \right)\end{aligned}$$

This confirms linearity of net worth with  $v(\mathbf{s}, x, d) = \nu_x(\mathbf{s})x - \nu_d(\mathbf{s})d$  with

$$\nu_x(\mathbf{s}) = (1 - \sigma) + \sigma \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 + \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] \right) \quad (39)$$

$$\nu_d(\mathbf{s}) = (1 - \sigma) + \sigma \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 + \beta_{DM} \mathbb{E} [\nu(\mathbf{s}', \epsilon')] R_d \right). \quad (40)$$

Now we turn to the bank's problem at the secondary market. The optimal portfolio choice implies that

$$\frac{\nu_{EM,(b,z)}(\mathbf{s})}{q_{EM,(b,z)}(\mathbf{s})} = \frac{\omega (\alpha A_{DM}^{\alpha-1} + 1 - \delta)}{q_{DM}(\mathbf{s})} \quad (41)$$



for all assets with positive holdings in the secondary market. Using (41) and conjecturing that the borrowing constraint is binding at all states, we can rewrite the constraints of problem (25) as

$$\frac{q_{DM}(\mathbf{s}, \epsilon)}{\omega \epsilon (\alpha A_{DM}^{\alpha-1} + 1 - \delta)} x = n + \kappa x, \quad (42)$$

Substituting (39), (40) and (42) into the objective function yields

$$\nu(\mathbf{s}, \epsilon)n = \left( (1 - \sigma) + \sigma \left( \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 + \beta_{DM} \left( \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - \kappa \mathbb{E}[\nu(\mathbf{s}', \epsilon')] R_d \right) \right) \right) \left( \frac{n}{\left( \frac{q_{DM}(\mathbf{s}, \epsilon)}{\omega (\alpha A_{DM}^{\alpha-1} + 1 - \delta)} - \kappa \right)} \right)$$

which confirms linearity of the secondary market problem.  $\square$

#### APPENDIX D. MAPPING THE MODEL TO EMPIRICAL RESULTS

This section discusses in detail the mapping of the model to the empirical regressions conducted in section 2. In these regressions we measure the effect of changes in the value of equity of global banks on the secondary market prices of the EM bonds that these banks hold. The model has the same variables that were measured in the data: secondary market prices are  $q_{EM,(b,z)}(\mathbf{s}, \epsilon)$  and the value of equity (at the secondary market stage) of the global banks that hold these bonds is given by  $\nu(\mathbf{s}, \epsilon)N(\mathbf{s}, \epsilon)$ , where is the average net worth of banks that hold that bond (i.e. banks in trading network  $\epsilon$ ). Both of these variables are endogenous in the model, so we will interpret the Lehman episode as a fall in  $\omega$  together with dispersion in realized returns  $\epsilon$  across trading networks. We then run a regression of the change in secondary market prices of each trading network on the change in the market value of the average net worth of those banks in the trading network.

#### APPENDIX E. SOLUTION METHOD

As discussed in Appendix C, our model agents' heterogeneity and aggregate uncertainty imply that the distribution of assets in the world economy,  $\Delta$ , an infinite-dimensional object, is a state variable in agents' individual problems. To solve for the equilibrium of the model numerically, we follow a common practice in existing algorithms and use as state variables a set of statistics that summarize this distribution (see Algan et al., 2014, for a review of algorithms to solve models with heterogeneous agents and aggregate uncertainty).

The detailed choices in our solution method are guided by three particular features of our model. First, individual EMs' problems involves a default choice without commitment, which requires the use of global methods in the solutions of these problems. Second, with default

risk, the degree of aggregate uncertainty in the economy significantly affects the debt-price schedules EMs face, as well as their policy functions. Therefore, we choose a method that uses the statistics summarizing the aggregate distribution as part of the state variables in the agents' individual problems.<sup>14</sup> The curse of dimensionality in the solution of these problems then naturally limits the dimension of the vector of states summarizing the distribution of assets. Finally, in our economy, the debt-price schedules individual EMs face depend on the perceived policy of banks' DM-firm-invested assets,  $\tilde{A}_{DM}(\mathbf{s}_+)$ , which governs DM firms' marginal product of capital. In equilibrium, perceived policies, in turn, must coincide with actual policies. To avoid inaccuracies originated in this perceived policy function, we instead choose an auxiliary aggregate variable  $\hat{A}_{DM}$ , describing aggregate investment in DM firms at the end of the period, as a state variable in agents' individual problems. Using  $\hat{A}_{DM}$  as a state also has the advantage that the approximate solution is always consistent with market clearing.

From these considerations, our approximate solution considers the following problems for individual agents. For global banks, we express their recursive problem as

$$\begin{aligned} \nu(\mathbf{s}, \epsilon) = & \left( (1 - \sigma) + \sigma \left( \left( \frac{1}{4\phi} \left( \beta_{DM} \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - 1 \right)^2 \right. \right. \\ & \left. \left. + \beta_{DM} \left( \mathbb{E} \left[ \nu(\mathbf{s}', \epsilon') \frac{q_{DM}(\mathbf{s}', \epsilon')}{q_{DM}(\mathbf{s})} \right] - \kappa \mathbb{E}[\nu(\mathbf{s}', \epsilon')] R_d \right) \right) \right) \\ & \frac{1}{\left( \frac{q_{DM}(\mathbf{s}, \epsilon)}{\omega(\alpha A_{DM}^{\alpha-1} + 1 - \delta)} - \kappa \right)} \end{aligned} \quad (43)$$

$$\hat{A}'_{DM} = \mathcal{F}_A(s_x, \hat{A}_{DM}, m) \quad (44)$$

$$m' = \mathcal{F}_m(s_x, \hat{A}_{DM}, m) \quad (45)$$

where  $\mathcal{F}_A(\cdot)$  and  $\mathcal{F}_m(\cdot)$  denote forecasting rules assumed to be used by agents under the approximate solution, and  $m$  is a set of moments describing the distribution  $\Delta$ . Note that once the variable  $\hat{A}_{DM}$  is included as a state, the statistics summarizing the distribution  $\Delta$  only matter for forecasting  $\hat{A}'_{DM}$ .

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<sup>14</sup>The relevance of the degree of aggregate uncertainty in our model makes us depart from an algorithms that involves perturbation methods around a solution of the model with no aggregate uncertainty (e.g., [Reiter, 2009](#)), which have typical computational speed and allow for a large set of state variables.

For individual EMs, their repayment decision under our approximate solution is characterized by

$$V(b, z, s_x, \hat{A}_{\text{DM}}, m) = \max_{\iota} \iota V^r(b, z, s_x, \hat{A}_{\text{DM}}, m) + (1 - \iota) V^d(z, s_x, \hat{A}_{\text{DM}}, m), \quad (46)$$

where  $V^r(b, z, s_x, \hat{A}_{\text{DM}}, m)$  denotes the value of repayment described by

$$V^r(b, z, s_x, \hat{A}_{\text{DM}}, m) = \max_{b'} u(c) + \beta \mathbb{E} \left[ V(b', z', s'_x, \hat{A}'_{\text{DM}}, m') \right], \quad (47)$$

$$\text{s.t. } c = y_{\text{EM}} + z + q(b', z, s_x, \hat{A}_{\text{DM}}, m) b' - b, \quad (44), (45),$$

$$q(b', z, s_x, \hat{A}_{\text{DM}}, m) = \frac{\mathbb{E}[v(s'_x, \hat{A}'_{\text{DM}}, m') \tilde{v}(b', z', s'_x, \hat{A}'_{\text{DM}}, m')]}{\mathbb{E}[v(s'_x, \hat{A}'_{\text{DM}}, m') \mathcal{R}_{\text{DM}}(z'_{\text{DM}}, \hat{A}'_{\text{DM}})]},$$

and  $V^d(z, s_x, \hat{A}_{\text{DM}}, m)$ , the value of default, is given by

$$V^d(z, s_x, \hat{A}_{\text{DM}}, m) = \max_{b'} u(c) + \beta \mathbb{E} \left[ \phi V^r(0, z' s'_x, \hat{A}'_{\text{DM}}, m') + (1 - \phi) V^d(z', s'_x, \hat{A}'_{\text{DM}}, m') \right], \quad (48)$$

$$\text{s.t. } c = \mathcal{H}(y_{\text{EM}} + z), \quad (44), (45).$$

For the forecasting rules, our benchmark algorithm follows [Krusell and Smith \(1998\)](#) in parameterizing an assumed functional form for the rule and using an iterative procedure with model-simulated data to estimate the parameters of the functional form.<sup>15</sup> To make the procedure parsimonious, we assume a log-linear forecasting rule in the state variables and summarize the distribution of borrowing across EMs with the mean of the distribution.<sup>16</sup> Our algorithm then proceeds as follows:

- (1) Specify initial forecasting rules, denoted  $\mathcal{F}_A^j(\cdot)$  and  $\mathcal{F}_m^j(\cdot)$  for  $j = 0$ .
- (2) Solve individual agents' problems given the forecasting rules  $\mathcal{F}_A^j(\cdot)$  and  $\mathcal{F}_m^j(\cdot)$  for  $j = 0$ , using value function iteration.
- (3) Simulate data from the model using the policy functions obtained in (2) for a given sequence of exogenous variables,  $\tilde{s}_x \equiv \{s_{x,t}\}_{t=1}^T$ , where  $T$  is the time length of the panel of model-simulated data. Estimate the parameters of the forecasting rule with model-simulated data and denote the new forecasting rules  $\mathcal{F}_A^{j+1}(\cdot)$  and  $\mathcal{F}_m^{j+1}(\cdot)$ . Denoting by  $\mathcal{F}^j(\tilde{s}_x)$  the sequence of forecasts under the rules  $\mathcal{F}_A^j(\cdot)$  and  $\mathcal{F}_m^j(\cdot)$  for the sequence  $\tilde{s}_x$ , compute the distance  $\delta_{j+1} \equiv \|\tilde{\mathcal{F}}^{j+1}(\tilde{s}_x) - \tilde{\mathcal{F}}^j(\tilde{s}_x)\|$ .

<sup>15</sup>We are currently working on a version of our algorithm using parametrized cross-sectional distributions as in [Algan et al. \(2010\)](#).

<sup>16</sup>Considering richer forecasting rules lead to convergence problems in the iterative procedure's rule.

- (4) Update forecast rules and iterate in steps (2) and (3) for  $j = 1, 2, 3, \dots$ , until  $\delta_{j+1}$  is sufficiently small.