Global Banks and Systemic Debt Crises[⋆]

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Abstract. We study the role of global financial intermediaries in international lending. We construct a model of the world economy, where heterogeneous borrowers issue risky securities purchased by financial intermediaries. Aggregate shocks transmit internationally through financial intermediaries' net worth. The strength of this transmission is governed by the degree of frictions intermediaries face financing their risky investments. We provide direct empirical evidence on this mechanism showing that, around Lehman Brothers' collapse, emerging-market bonds held by more-distressed global banks experienced larger price contractions. A quantitative analysis of the model shows that global financial intermediaries play a relevant role driving borrowing-cost and consumption fluctuations in emerging-market economies, both during debt crises and in regular business cycles. The portfolio of financial intermediaries and the distribution of bond holdings in the world economy are key to determine aggregate dynamics.

Keywords: Financial intermediaries, international lending, external debt crises, consumption adjustment, heterogeneous-agent models

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1. Introduction

Debt crises in emerging-market economies are global in nature, affecting multiple economies in a synchronized fashion and involving 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 late 1990s, linked to the collapse of the LTCM fund; and the recent global financial crisis, linked to U.S. and European banks and affecting most emerging-market 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 out 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 financial intermediaries in international lending. We do so by developing a heterogeneous-agents model of the world economy with risky lending, and providing new empirical evidence on the relationship between global financial intermediaries and emerging-market debt prices. In the model, borrowers issue risky securities purchased by financial intermediaries, and aggregate shocks transmit internationally through financial intermediaries' net worth. The strength of this mechanism is governed by the degree of financial frictions that intermediaries face financing their risky investments. We then provide empirical evidence on this mechanism showing that well-identified shocks to financial intermediaries' net worth affect bond prices in emerging-market economies. We exploit variation in prices of emerging-market bonds with similar observed characteristics during a short window around Lehman Brothers' bankruptcy, and document larger price drops in bonds held by more-affected financial intermediaries. Finally, we conduct a quantitative analysis of the model, which uses the empirical evidence as well as other key data, and show that global financial intermediaries play a relevant role driving fluctuations of borrowing costs and consumption in emerging-market economies, both during debt crises and in regular business cycles.

We begin by laying out a model of risky international lending. We model a world economy composed of a set of heterogeneous emerging economies facing systemic and idiosyncratic income shocks, which borrow from developed economies without commitment. Global financial firms intermediate in this lending process, but face financial frictions linking investments in risky securities to their net worth. The model, while rich enough to be quantified and mapped to 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 equate global supply and demand of funds for risky assets. This way, negative aggregate shocks lower financial intermediaries' net worth, contract the supply of funds, and increase the intermediation premium. The strength of this mechanism is governed by financial frictions faced by intermediaries, which determine their marginal costs of external finance. When these marginal costs are large, shocks that affect intermediaries' net worth lead to large effects on emerging-market bond prices, as they require higher returns to be willing to raise external finance and purchase risky securities. In fact, in the opposite extreme case, when intermediaries face no financial frictions, debt prices do not respond to changes in the the intermediaries' net worth.

Motivated by the model's predictions, we analyze the empirical relationship between emerging-market bond prices and financial institutions' net worth. In the aggregate, these two variables are strongly negatively correlated, with periods such as the recent global financial crisis being characterized by spikes in emerging-market spreads. However, the main empirical challenge for drawing conclusions out of this relationship is that changes in financial institutions' net worth can be linked to other factors driving emerging-market default risk. Therefore, we propose an empirical strategy that builds on the empirical-finance literature and exploits high-frequency variation of individual bond prices. We identify the effect changes in global financial intermediaries' net worth on emerging-market bond prices by relating the average contraction in the net worth of the institutions holding a particular bond in a narrow window around the Lehman-bankruptcy episode to its subsequent price drop. The key idea of this empirical strategy is that bonds of a given country–sector with comparable observable characteristics have similar default and liquidity risk, but are held by financial intermediaries differentially affected during the Lehman-bankruptcy episode. To measure the average contraction in the net worth of the financial intermediaries holding a particular bond, we collect data on each financial intermediary's holdings 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 50% larger than that of the average bond.

We then use a quantitative version of the model, disciplined by our empirical estimates as well as other key data, to assess the relevance of global financial intermediaries in international lending. The model, solved with a combination of global methods and an approximation of the distribution of assets in the world economy, is consistent with key comovements of international asset prices, as well as with individual emerging-economy business cycles. We highlight two main results from the quantitative model. First, global banks play a key role in the emerging economies' borrowing costs and consumption dynamics, both during debt crises and in regular business cycles. In debt crises, we show that a contraction in the net worth of global financial intermediaries similar to that observed during 2007–2009 can explain more than two thirds of the increase in borrowing costs and more than a third of the consumption adjustment, or "sudden stop," observed in emerging economies during this period. Moreover, global financial intermediaries are also relevant in regular business cycles, accounting for 40% of the fluctuations in emerging economies' borrowing costs, with the remaining explained by fluctuations in the default risk.

Our second main result is that the exposure of global financial intermediaries to emerging economies, as well as the distribution of debt in the world economy, matter for the type of role financial intermediaries play in the transmission and amplification of aggregate shocks. With the current observed exposure (around 10% of risky assets), global financial intermediaries mostly play a role in transmitting shocks originating in developed economies. However, when this exposure is higher, around the levels observed in the 1980s (three times current levels), global financial intermediaries also amplify shocks originating in emerging economies, through a feedback effect between the supply of funds and emerging economies' default rates. In this case, the distribution of debt shapes the response to and magnitude of the feedback effect, with more dispersion in debt positions leading to higher default rates for a given negative output shock. In this sense, our model captures the changing nature of historical debt crises in emerging economies, and highlights key variables that can be relevant for policy in the future.

Related literature

Our paper contributes to several strands of the literature. In the first place, the growing body of research on financial intermediaries and asset prices argues that financial intermediaries are likely to be the marginal investor in several asset markets, and links asset-price dynamics to frictions in financial intermediation. For examples of theories, see Gertler and Kiyotaki (2010); He and Krishnamurthy (2011, 2013); Brunnermeier and Sannikov (2014); for examples of empirical evidence, see Adrian et al. (2014); He et al. (2017); see also He and Krishnamurthy (2018) for a recent survey. The closest papers in the role of financial intermediaries in international asset prices are Gabaix and Maggiori (2015) and Maggiori (2017), who study exchange-rate determination in imperfect financial markets. Our contribution to this literature is twofold. First, our empirical analysis provides direct evidence on the intermediary-based asset pricing channel for emerging-market debt. Second, the analysis of our world-economy model shows that the wealth dynamics of global financial intermediaries are central in determining the aggregate emerging market borrowing and consumption dynamics.

In the second place, our paper is also related to the literature on sovereign debt and default. This literature argues that default risk is an important driver of the dynamics of external borrowing and consumption in emerging economies (see, for example, Aguiar and Gopinath, 2006; Arellano, 2008). In a recent survey, Aguiar et al. (2016) suggest the relevance of enriching the lender side in sovereign-debt models. To date, this has been done by introducing more-flexible stochastic discount factors in the pricing of debt (see, for example, Borri and Verdelhan, 2011; Lizarazo, 2013; Tourre, 2017; Bianchi et al., 2018; Bocola and Dovis, 2019; Bai et al., 2019), and analyzing amplification and contagion through lenders (see Park, 2014; Bocola, 2016; Arellano et al., 2017). Our paper contributes to this literature by analyzing the role of global financial intermediaries in risky international lending and debt crises, through the lens of a heterogeneous-agents model of the world economy.

In the third place, the paper is related to the literature that studies large adjustments in consumption and the current account during external crises, a phenomenon often labeled "sudden stops." 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, Calvo and Mendoza, 1996; Mendoza, 2002, 2010; Bianchi, 2011). We show that a large part of these dynamics can be explained by shocks to other risky-debt markets transmitted through global financial intermediaries. In this sense, our results provide a micro foundation for exogenous fluctuations in external borrowing costs, which have been identified as key drivers of consumption, output, and exchange-rate dynamics (see, Neumeyer and Perri, 2005; García-Cicco et al., 2010).

Our paper is also related to the literature on international asset prices and the global financial cycle. This literature has documented a large comovement in debt and equity prices across countries (see, for example, Forbes and Rigobon, 2002; Longstaff et al., 2011; Borri and Verdelhan, 2011), and a strong link between international capital flows, domestic lending and business cycles (see, for example, Gourinchas and Rey, 2007; Devereux and Yetman, 2010; Cetorelli and Goldberg, 2011; Rey, 2015; Baskaya et al., 2017; Perri and Quadrini, 2018; Avdjiev et al., 2018). Our paper shows that global financial intermediaries can play a key role in these patterns.

Finally, our paper is related to the growing body of research that has studied the role of agents' heterogeneity in the transmission of aggregate shocks. Most of the advances of this literature took place in the context of closed economies (prominent examples include Krusell and Smith, 1998; Khan and Thomas, 2008; Kaplan et al., 2018). We contribute to this literature by analyzing the role of agent heterogeneity in the transmission of international shocks, and show that the composition of financial intermediaries' balance sheet is key for determining the relevance of the distribution of risky debt in the world economy.

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

2. A Model of the Global Debt Market

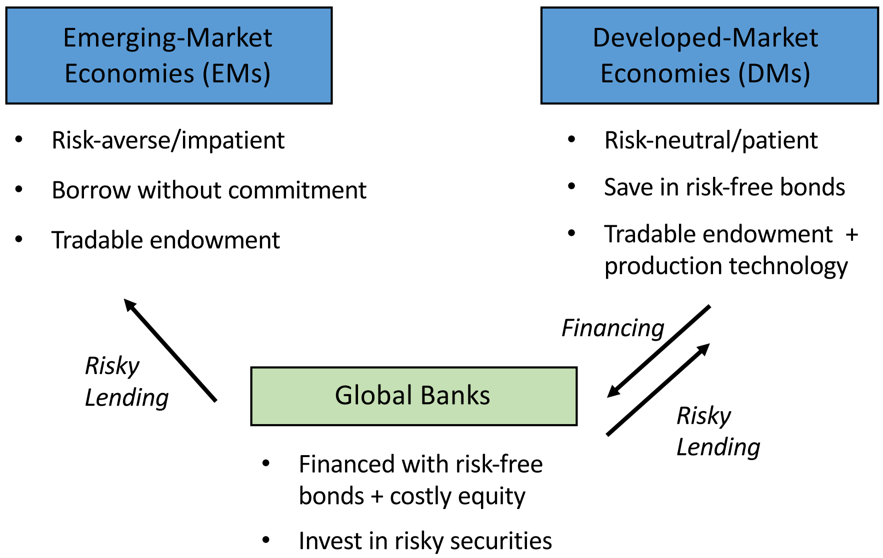
We construct a framework to study the role of financial intermediaries in global lending markets. The world economy includes a set of emerging-market economies (EMs) and a set of developed-market economies (DMs). Households in these two types of economies differ in their preferences, giving rise to international lending. EM households are risk-averse and impatient, while DM households are risk-neutral and patient. Households in EMs are endowed with a stochastic stream of tradable goods with systemic and idiosyncratic components leading to heterogeneity across EMs. We interpret household borrowing in a broad sense, capturing direct international borrowing, sovereign borrowing, and borrowing through other agents (e.g., local banks). EMs lack commitment to repay their debt and can default.

The model's key feature is that international lending is mediated by financial intermediaries (*global banks*). DM households provide finance to global banks using a risk-free bond (*deposits*) and equity. Intermediaries face frictions in their intermediation activity that limit their ability to raise funds from DMs. They lend these funds to EM households using risky bonds or invest them in risky DM technologies. Figure 1 graphically represents the global economy.

2.1. *Emerging Economies*

There is a continuum of mass μ_{EM} of heterogeneous emerging economies, indexed by $i \in [0, \mu_{\text{EM}}]$. Each emerging economy is populated by a unit mass of identical households with

FIGURE 1. The World Economy



preferences described by the lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_{\text{EM}}^t u(c_{it}), \tag{1}$$

where $u(\cdot)$ is increasing and concave, c_{it} denotes consumption of the representative EM household i in period t, and $\beta_{\text{EM}} \in (0, 1)$ is the EM household's subjective discount factor. Each period, EM households receive a stochastic endowment of tradable goods, with a systemic component $y_{\text{EM}t}$, 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 ($\iota_{it} = 1$) or to default ($\iota_{it} = 0$). Defaulting households loose 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 have access to external credit markets can issue long-term bonds with a deterministic decay rate. In particular, by issuing one unit of the bond in period t, the government promises to repay one unit of goods in period $t + 1$, ξ in period $t + 2$, ξ^2 in period $t + 3$, and so on, and in exchange receives $q_{\text{EM}t}^i$ units of goods in period t.[1] Denoting by b_t, the amount of coupons to be

[1]The convenience of this type of contract, frequently used in the sovereign-debt and corporate-finance literature, is its recursive structure. The case of $\xi = 0$ corresponds to short-term debt, and as ξ increases, so does the maturity of the bond.

paid in period t, the law of motion of these coupons is given by $b_{t+1} = \xi b_t + i_t$, where i_t denotes the period t issuance of new bonds. Households' sequential budget constraint in periods with access to international markets is then

$$c_{it} = y_{\text{EM}t} + z_{it} + q^i_{\text{EM}t} \left(b_{it+1} - \xi b_{it}\right) - b_{it}. \tag{2}$$

Households excluded from global capital markets simply consume their endowments

$$c_{it} = \mathcal{H}(y_{\text{EM}t} + z_{it}), \tag{3}$$

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 A.1. As is standard in default problems, the price $q^i_{\text{EM}t}$ depends on the aggregate and individual states of the households as well as on its borrowing choices, b_{it+1}.

In partial equilibrium, this problem is equivalent to a standard borrowing problem in a small open economy with default (e.g., Aguiar and Gopinath, 2006; 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.

2.2. *Developed Economies*

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t_{\text{DM}} c_{\text{DM}t}, \tag{4}$$

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

Each period, households receive an endowment of tradable goods y_{DM} and time to work $\overline{h}$.[2] They can save in risk-free bonds issued by global banks (i.e., deposits) that pay a return R_{dt} for every unit of deposit in $t+1$. Their sequential budget constraint is given by

$$c_{\text{DM}t} = y_{\text{DM}} + w_t \overline{h} + R_{dt} d_t - d_{t+1} + \pi_t \tag{5}$$

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 π_t denotes net payouts from global banks.

[2]We introduce the endowment y_{DM} to make explicit that our framework can accommodate production sectors in DMs that are not financed by global banks, for instance, small firms financed by regional U.S. banks. Due to risk-neutrality of DM households, making this process stochastic would not play any role in equilibrium.

The DM household's problem is to choose state-contingent plans $\{c_{\text{DM}t}, d_{t+1}\}_{t=0}^{\infty}$ to maximize (4) subject to (5), taking as given prices $\{R_{dt}, w_t\}_{t=0}^{\infty}$ and transfers $\{\pi_t\}_{t=0}^{\infty}$. Households' optimization delivers a constant equilibrium interest rate for deposits, $R_{dt} = \beta_{\text{DM}}^{-1} \equiv R_d$.

Nonfinancial firms. DM economies are also populated by representative nonfinancial firms with access to technologies to produce tradable goods $y_{\text{F}t}$ and accumulate capital k_{t+1}:

$$y_{\text{F}t} = (\omega_t k_t)^{\alpha} h_t^{(1-\alpha)}, \tag{6}$$

$$k_{t+1} = \omega_t \left(1-\delta\right) k_t + x_t, \tag{7}$$

with $\alpha, \delta \in (0,1)$, where h_t are hours of work, x_t is firm investment, and ω_t is an aggregate shock to the capital quality with a bounded support.[3] The shock to DM firms is potentially correlated with the aggregate shock to EMs, y_{EM}, with the correlation between the two shocks given by the parameter $\rho_{\text{EM,DM}} \in [-1,1]$. Nonfinancial DM firms are owned by global banks, as we describe next.

2.3. *Global Banks*

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

$$\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta_{\text{DM}}^{s-t} \pi_{jt+s}, \tag{8}$$

where π_{jt} denotes net payments of bank j to households in period t. Each bank can invest in two types of risky securities, claims on nonfinancial firms from DM economies, $a_{\text{DM}jt}$, and bonds issued by EMs, $\{a^i_{\text{EM}jt}\}_{i\in\mathcal{I}_t}$, where i indexes a particular EM economy and $\mathcal{I}_t$ the set of EMs that issue bonds in period t. The amount of final goods that each bank obtains from these investments, or net worth, is given by

$$n_{jt} = \int_{i\in\mathcal{I}_{t-1}} R^i_{\text{EM}t} q^i_{\text{EM}t-1} a^i_{\text{EM}jt-1}\,\mathrm{d}i + R_{\text{DM}t} q_{\text{DM}t-1} a_{\text{DM}jt-1} - R_d d_{jt-1}, \tag{9}$$

where $\{R^i_{\text{EM}t}\}_{i\in\mathcal{I}_{t-1}}$ is the set of returns of EM bonds in period t and $R_{\text{DM}t}$ is the return of the claims of nonfinancial firms in DM economies in period t. Banks use their net worth, as well as

[3] Shocks to the quality of capital are frequently used in the macrofinance literature (see, for example, Bernanke et al., 1999; Gertler and Kiyotaki, 2010) as a stylized disturbance that can generate realistic variations in investment returns.

risk-free deposits from DM households, to finance investments in risky securities and dividend payments, div_{jt}:

$$n_{jt} + d_{jt} = \int_{i \in \mathcal{I}_t} q^i_{\text{EM}t} a^i_{\text{EM}jt} \, \text{d}i + q_{\text{DM}t} a_{\text{DM}jt} + div_{jt}. \tag{10}$$

Banks face frictions to finance their investments. First, they face a borrowing constraint, linking their deposits to their net worth,

$$d_{jt} \leq \kappa n_{jt}, \tag{11}$$

where $\kappa > 0$.[4] In addition, 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 $\mathcal{C}(div, n) = \phi\left(\frac{-div}{n}\right)$. Following the corporate-finance literature, these costs are designed to capture flotation costs and adverse-selection premia associated with raising external equity (see, for example, Hennessy and Whited, 2007). We interpret ϕ in a broad sense, as capturing the marginal cost of raising external finance, which includes outside equity and other sources of external finance like issuing costly risky debt, or expanding the customer base in the case of asset managers.

The net payouts to DM households in a given period are then given by

$$\pi_{jt} = div_{jt}(1 + \mathbb{I}_{div_{jt}<0} \mathcal{C}(div_{jt}, n_{jt})). \tag{12}$$

Finally, to ensure that banks do not outgrow their financial frictions, we assume that they exit with an exogenous i.i.d. probability $(1 - \sigma)$ (see, for example, Gertler and Kiyotaki, 2010). Each period, a mass of $(1 - \sigma)$ new banks enter the economy, so that the total mass of global banks is always fixed at one. New banks are endowed with net worth $\overline{n}$.

The bank's problem is to choose state-contingent plans $\{\{a^i_{\text{EM}jt}\}, a_{\text{DM}jt}, d_{jt}, div_{jt}\}$ to maximize (8) subject to (9), (10), (11), and (12). Appendix A.1 shows the bank's recursive problem. Focusing on an equilibrium in which banks always face excess returns (i.e., $d_{jt} < 0$ for all t), our formulation gives rise to a problem that is linear in net worth, and whose solution is characterized by the constraint (11) holding with equality and

$$R^e_{\text{EM}it} = R^e_{\text{DM}t} \equiv R^e_t \tag{13}$$

$$-2\phi\left(\frac{div_{jt}}{n_{jt}}\right) = \beta_{\text{DM}} R^e_t - 1 \tag{14}$$

[4]This borrowing constraint can emerge from an agency friction by which the banker can use the funds raised with deposits to start a new franchise. Alternatively, the constraint can also be interpreted as the presence of regulatory capital requirements.

for any solution with $a^i_{\text{EM}t} > 0$, $a_{\text{DM}t} > 0$, where $R^e_{\text{EM}it} \equiv \mathbb{E}_t[v_{t+1} R^i_{\text{EM}t+1}]$, $R^e_{\text{DM}t} \equiv \mathbb{E}_t[v_{t+1} R_{\text{DM}t+1}]$, and v_t is the marginal value of net worth for global banks, formally defined in Appendix A.1. Equation (13) implies that the global bank equates expected returns across asset classes, while equation (14) implies that banks equate the marginal cost of external finance to the discounted expected return on risky assets.

2.4. *Equilibrium*

Definition 1 defines a competitive equilibrium in the global economy.

Definition 1. *Given global banks' initial portfolios* $((a^i_{\text{EM}j0})_{i\in[0,\mu_{\text{EM}}]}, a_{\text{DM}j0}, d_{j,0})_{j\in[0,1]}$, *EM households' initial debt positions* $(b_{it})_{i\in[0,\mu_{\text{EM}}]}$, *and state-contingent processes* $\{\omega_t, y_{\text{EM}t}, (z_{it}, \zeta_{it})_{i\in[0,\mu_{\text{EM}}]}\}$, *a competitive equilibrium in the global economy is a sequence of prices* $\{w_t, (q^i_{\text{EM}t})_{i\in[0,\mathcal{I}_t]}, q_{\text{DM}t}\}_{t=0}^{\infty}$ *and allocations for DM households* $\{c_{\text{DM}t}, d_{t+1}\}_{t=0}^{\infty}$, *nonfinancial firms* $\{h_t, k_{t+1}\}_{t=0}^{\infty}$, *global banks* $\{((a^i_{\text{EM}jt+1})_{i\in[0,\mathcal{I}_{t+1}]}, a_{\text{DM}jt+1}, d_{jt+1})_{j\in[0,1]}\}_{t=0}^{\infty}$, *and EM households* $\{(c_{it}, b_{it+1}, \iota_{it})_{i\in[0,\mu_{\text{EM}}]}\}_{t=0}^{\infty}$ *such that*

i. Allocations solve agents' problems at the equilibrium prices,

ii. Assets and labor markets clear.

iii. The set of EMs with access to credit markets $\mathcal{I}_t$ *evolves according to the repayment decisions and the re-entry stochastic process.*

In equilibrium, clearing of asset markets implies that global banks' investment in each risky security traded in the global economy equalizes the amount of that type of securities issued:

$$A^i_{\text{EM}t} \equiv \int_{j\in[0,1]} q^i_{\text{EM}t} a^i_{\text{EM}jt}\, \mathrm{d}j = q^i_{\text{EM}t} b_{it+1},$$

$$A_{\text{DM}t} \equiv \int_{j\in[0,1]} q_{\text{DM}t} a_{\text{DM}jt}\, \mathrm{d}j = k_{t+1}.$$

The returns of securities are given by $R^i_{\text{EM}t+1} = \frac{\iota_{it+1}\left(1+\xi q^i_{EMt+1}\right)}{q^i_{EMt}}$ and $R_{\text{DM}t+1} = \frac{\omega_{t+1}\left[\alpha A^{\alpha-1}_{\text{DM}t}+1-\delta\right]}{q_{\text{DM}t}}$.

2.5. *The Role Global Banks in International Lending*

We now theoretically discuss the channels through which global banks affect EM debt. 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 Section 4, where we analyze the quantitative version of our model. The evolution of equilibrium variables depends on the global banks' aggregate initial portfolio (their investments in EMs, DMs, and their deposits), as well as on the joint distribution of individual debt positions and idiosyncratic endowments.

Given a path of future prices and allocations, the determination of current EM required returns and borrowing can 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:

$$\mathcal{A}^s_t(R^e_{\text{EM}t}, N_t) \equiv \int_{i\in\mathcal{I}_t}\int_{j\in[0,1]} q^i_{\text{EM}t} a^i_{\text{EM}jt}\,\mathrm{d}j\,\mathrm{d}i$$

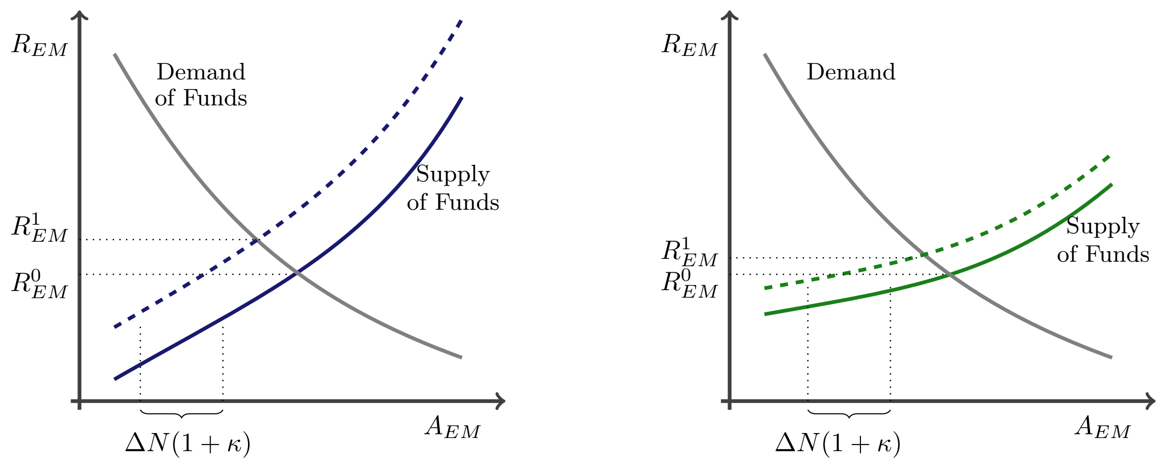
$$= \underbrace{N_t(1+\kappa)}_{\substack{\text{Net worth}\\ +\text{New deposits}}} + \underbrace{\mathcal{E}(R^e_{\text{EM}t}, \phi)N_t}_{\text{Equity issuance}} - \underbrace{\mathcal{A}_{\text{DM}t}(R^e_{\text{EM}t}, \alpha)}_{\text{Investment in DM firms}}, \tag{15}$$

where $N_t \equiv \int_{j\in[0,1]} n_{jt}\,\mathrm{d}j$ is banks' aggregate net worth in at t, $\mathcal{E}(R^e_{\text{DM}t}, \phi) \equiv \int_{j\in[0,1]}\left(\frac{-div_{jt}}{n_{jt}}\right)\mathrm{d}j$ denotes the aggregate equity raised by banks, and $\mathcal{A}_{\text{DM}t}(R^e_{\text{EM}t}, \alpha) \equiv A_{\text{DM}t}$ denotes banks' investments in DM firms.[5] This relationship between funds supplied and required returns is increasing (i.e., $\frac{\partial A^s_t}{\partial R^e_{\text{EM}t}} > 0$). To increase the amount of funds supplied, given that the limited liability constraint binds, banks must either issue more equity or decrease their DM investments, both of which require higher EM returns. Issuing more equity is costly due to its increasing marginal costs, and decreasing investments in DM firms is costly because it depresses the aggregate level of capital and increases its marginal product. The supply elasticity is governed by two key parameters: the marginal cost of raising external finance, governed by ϕ, and the degree of decreasing returns in DM firms, α. Figure 2 graphically represents the aggregate supply of funds for high and low costs of raising equity. Lower marginal costs of issuing equity yield greater sensitivity of the supply of funds to changes in required returns. When the marginal costs of equity are low, an increase in required returns not only attracts more funds that were initially allocated to the DM productive sector, but also increases the desired level of capitalization of the aggregate banking system. In the extreme case in which equity costs become negligible ($\phi \to 0$), the aggregate supply curve becomes flat in the plane $(A_{\text{EM}t}, R^e_{\text{EM}t})$.

[5]This supply is obtained by aggregating the supply of funds of each global bank to each EM economy. The analysis allows for aggregation at the this level since global banks' optimal portfolio allocation implies equal required returns, and banks' policies are linear in their net worth. Function $\mathcal{E}(R^e_{\text{DM}t}, \phi)$ can be obtained from (14). Function $\mathcal{A}_{\text{DM}t}(R^e_{\text{EM}t}, \alpha)$ can be obtained by combining banks' optimality condition (13), and the definition of return $R_{\text{DM}t}$. Solving for $A_{\text{DM}t}$ yields $A_{\text{DM}t} = \left\{\left[R^e_{\text{EM}t} - (1-\delta)\right](\omega_{t+1}\alpha)^{-1}\right\}^{\frac{1}{\alpha-1}}$.

FIGURE 2. Equilibrium in the EM Debt Market: The Role of Global Banks' Financial Frictions

(A) High Costs of Equity Issuance (B) Low Costs of Equity Issuance



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

$$\mathcal{A}_t^d(R^e_{\text{EM}t}) = \int_{i \in \mathcal{I}_t} \frac{1}{R^e_{\text{EM}t}} \iota_{it+1} \left(1 + \xi q^i_{EMt+1}\right) b_{it+1} \, \mathrm{d}i. \tag{16}$$

The aggregate demand is also depicted in Figure 2 with a decreasing relationship between returns and quantities. Although the slope of the aggregate demand 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 2 depicts the equilibrium aggregate borrowing and required returns as the intersection between aggregate demand and supply of funds. This analysis takes as given other equilibrium variables, particularly global banks' net worth. Aggregate net worth can be obtained by integrating the evolution of net worth (9) across banks:

$$N_t = \sigma \left[\int_{i \in \mathcal{I}_{t-1}} \iota_{it} \left(1 + \xi q^i_{EMt}\right) A^i_{\text{EM}t-1} \, \mathrm{d}i + R_{\text{DM}t} A_{\text{DM}t-1} - R_d D_{t-1} \right] + (1-\sigma)\overline{n}. \tag{17}$$

Consider the effect of an unexpected negative shock to the return of the DM security, ω_t, which implies a low return on DM investments and negatively affects global banks' net worth. The strength of the impact on net worth depends on global banks' exposure to DM investments. A lower net worth reduces the amount of deposits that banks can roll over. This implies that banks have less resources available to purchase securities, which reduces the aggregate supply of funds for a given required return, as depicted by the dotted line in Figure 2a, and increases the equilibrium required return.

Consider, now, the effect of an unexpected negative shock to the systemic component of EM endowments, $y_{\text{EM}t}$. This shock affects the aggregate demand through the effect of lower endowments on desired individual borrowing decisions by each EM. Additionally, this shock also negatively affects the aggregate supply of funds and the net worth of global banks through an increase in default risk that lowers EM debt prices and decreases returns. The strength of the impact on net worth depends on global banks' exposure to EM investment and also on debt's distribution across emerging economies. If a larger fraction of EMs have high levels of debt, the increase in default risk is higher and so is the effect on banks' net worth. In section 4, we study the quantitative role of banks' exposure to EM debt and debt distribution in the amplification of shocks to $y_{\text{EM}t}$.

Finally, how EM returns respond to shocks to N_t, originated by either shocks to ω_t or $y_{\text{EM}t}$, depends on the banks' ability to recapitalize. In the model, this depends on the parameter ϕ that determines the marginal cost of issuing external finance. Consider an economy with high costs of equity issuance (high ϕ). In this economy, the excess supply of funds is steep because banks require a significant increase in returns to issue equity to finance purchases of additional risky securities. As shown in Figure 2a, a shock to N_t will have associated a large drop in prices, and a large increase in required returns, to induce equity issuance to purchase a given stock of securities. Consider, now, an economy with low ϕ. In this economy, it is less costly for banks to recapitalize and, therefore, prices and returns need to respond less to a shock to N_t of the same magnitude, to induce equity issuance to restore equilibrium (Figure 2b). In the extreme case in which banks can recapitalize costlessly, the excess supply becomes perfectly elastic, and N_t would have no effect on prices. Proposition 1 summarizes these results.

PROPOSITION 1. *If global banks face no financial frictions (i.e., $\phi = 0$), EM debt prices are given by*

$$q^i_{\text{EM}t} = \mathbb{E}_t\left[\beta_{DM}\iota_{it+1}\left(1+\xi q^i_{\text{EM}t+1}\right)\right].$$

Proof. If $\phi = 0$, (14) and the definition of R^e_t imply that $\frac{1}{\beta_{\text{DM}}} = \mathbb{E}_t\left[v_{t+1}\frac{\left(\iota_{it+1}+\xi q^i_{EMt+1}\right)}{q^i_{EMt}}\right]$. From banks' recursive problem (detailed in Section A.1), it follows that $v_t = 1$ for all t, leading to the stated result. □

Therefore, when global financial intermediaries can frictionlessly finance their investments in risky securities, the equilibrium for each individual economy is isomorphic to one in which debt is priced by DM households. A corollary of this result is that if, in addition, aggregate EM and DM shocks are orthogonal ($\rho_{\text{EM,DM}} = 0$), then shocks to DMs ω_t are uncorrelated with EM prices:

Corollary 1. *If $\phi = 0$ and $\rho_{\text{EM,DM}} = 0$, then $\text{cov}(\omega_t, q^i_{\text{EM}t}) = 0$ for all t and i.*

This analysis suggests that the degree of price drops in response to DM shocks (if unrelated to EM shocks) are highly informative of the degree of financial frictions faced by global institutions that price EM securities. The next section is aimed at analyzing empirical evidence linked to this relationship.

3. Empirical Evidence

We begin by highlighting aggregate patterns observed in the world economy that are relevant empirical counterparts of our model's predictions. We then describe our empirical work on the effect of changes in global financial institutions' net worth on EM debt prices, which constitutes new evidence on the mechanism stressed by the model and helps discipline our quantitative analysis in Section 4.

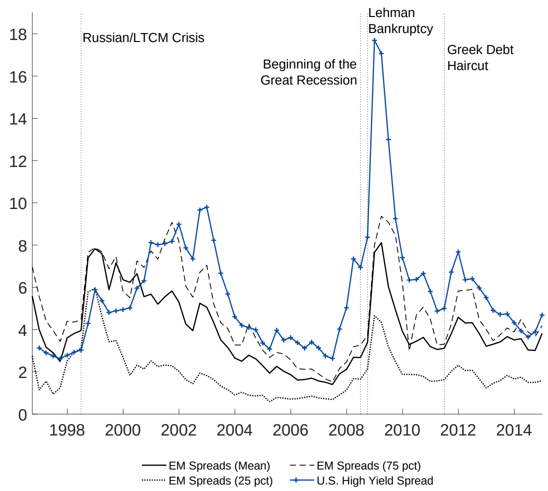
The objective of the empirical analysis is to identify the presence of fire sale effects on EM bond prices using micro data. These type of effects have also been identified in the empirical finance literature in the context of CDS and corporate bonds (Coval and Stafford, 2007; Mitchell et al., 2007; Siriwardane, 2019).

3.1. *Background: Aggregate Patterns*

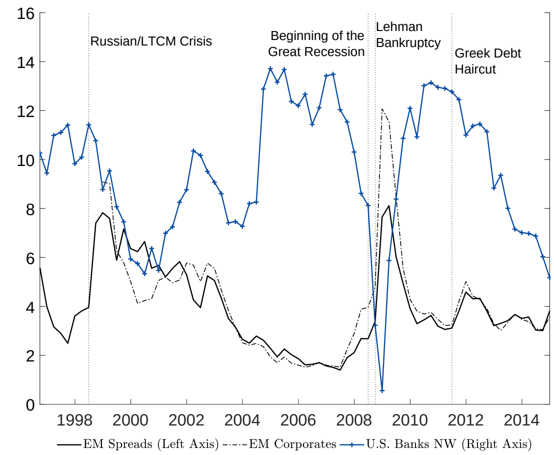
EM debt prices have a strong common component that has a tight link with global factors (Longstaff et al., 2011). We illustrate this in Figure 3a, which shows fluctuations of different percentiles of the distribution of EM-bond spreads, and their correlation with U.S. corporate spreads. The average correlation between the spread of an individual EM economy and the average EM-bond spread is 69%. Additionally, the correlation between average EM-bond spreads and U.S. corporate spreads is 50%. Furthermore, EM bond spreads comove negatively with global banks' net worth over recent decades, as shown in Figure 3b. The correlation between average EM-bond spreads and U.S. global banks' aggregate net worth is −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. These patterns are also consistent with the concept of the "global financial cycle" (Gourinchas and Rey, 2007; Rey, 2015).

Figure 3. Aggregate Patterns in the Global Debt Market

(A) Comovement of Bond Spreads



(B) EMs Bond Spreads and U.S. Banks' Net Worth



Notes: Panel (A) shows the spread of EM sovereign bonds and U.S. high-yield corporate bonds, expressed in percent. For EM sovereign spreads, the figure shows the mean spread of countries included in JP Morgan's Emerging Markets Bond Index (EMBI) and the 25th and 75th percentiles of the distribution. Data source: Bloomberg and Federal Reserve Bank of St. Louis. Panel (B) shows EM sovereign and corporate bond spreads and U.S. banks' net worth. Bond spreads are expressed as percentages and are computed as the average spreads across countries included in JP Morgan's EMBI and Corporate Emerging Markets Bond Index (CEMBI; for corporate spreads). Data source: Bloomberg. The U.S. global banks' net worth 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.

In our model, the presence of frictional global financial intermediaries in the market for risky debt could account for these patterns. As analyzed in the previous section, shocks that affect global banks' net worth lead to changes in required returns that jointly affect asset prices in EMs and DMs. However, these patters could also arise in a frictionless environment with asset returns driven by a common factor. In our model, this would correspond to the case in which the aggregate DM and EM shocks, ω_t and $y_{\text{EM}t}$, are correlated. Therefore, although aggregate evidence is consistent with the mechanisms highlighted in our model, there is also value in providing direct evidence that seeks to isolate the role of shocks affecting EM returns through its effect on global financial intermediaries' net worth. In the next subsections, we propose an empirical strategy to identify these effects based on exploiting price differences in bonds held by different global financial institutions.[6] We focus in a narrow window around Lehman Brother's bankruptcy on September 15, 2008, which constituted a large shock by which financial institutions were differentially affected and that, as we show below, was followed by dispersion in the yields of EM bonds with similar characteristics (default risk, maturity, liquidity). We next describe the data used in the empirical analysis, the empirical model, and results.

3.2. *Data and Descriptive Statistics*

This section summarizes the datasets used in the empirical analysis, and describes the construction of the main variables of interest. Further details on the description of the data can be found in Appendix C.

EM bond prices. We collect data on daily prices for risky sovereign and corporate bonds issued by countries that at some point were part of the EMBI.[7] The data sources are Bloomberg and Datastream, from which we obtain a sample of over 400 EM bonds (identified with different CUSIPs) with available daily price data. For each bond, we have information on the issuer, the bond maturity, its bid–ask spread, and amount issued, which we exploit in the empirical analysis to compare prices of bonds with similar characteristics. We compute the yield to maturities of bond prices using information on coupons and maturities of each individual bond. Around half of the bonds of our sample are sovereign bonds and half are corporate bonds, which span different sectors. In Appendix C, we report descriptive statistics of our sample of bonds per country and sector.

Our variable of interest is the change in yield to maturity in EM bonds following the Lehman episode. Figure 4a shows that EM bond yields experienced average daily increases in the two months after the Lehman episode, leading to a cumulative increase of four percentage points 40 days after the episode. Importantly, these daily increases in yields were heterogeneous across bonds with similar characteristics. In particular, Figure 4b shows the dispersion across daily changes in yields to maturity for bonds issued in the same country and sector, and with a similar

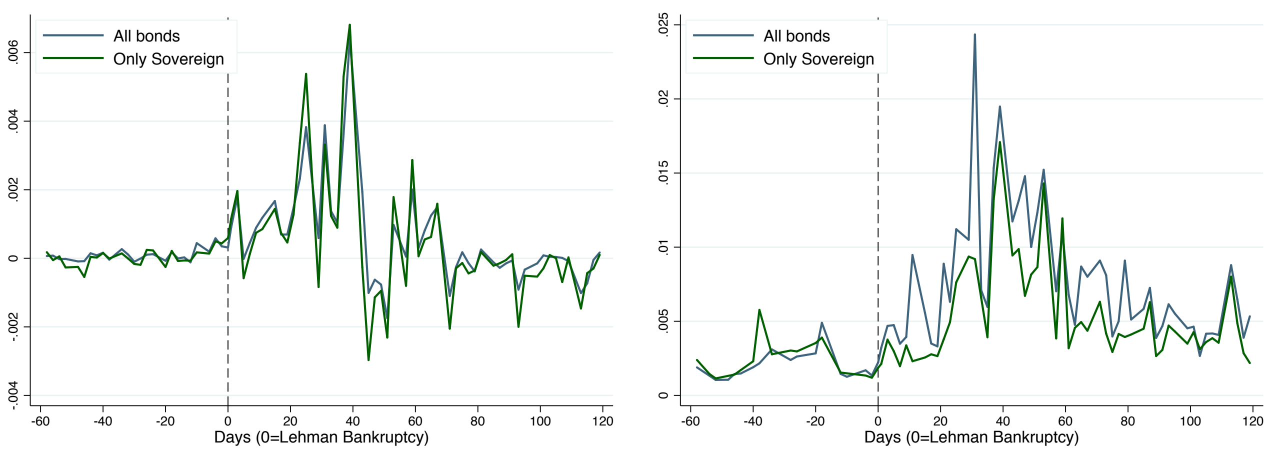
[6] Note that the source of variation in this empirical analysis is across bonds with different holders. In our model, we abstract from such source of variation to highlight the aggregate mechanism. We refer the interested reader to Appendix B, where we enrich our model to allow for the same source of variation as in the data.

[7] To capture risky bonds in our sample, we focus on countries whose sovereign credit rating (from Standard & Poor's) is below A. The set of 30 countries included in our sample are Argentina, Brazil, Colombia, Costa Rica, Croatia, Ecuador, Greece, India, Indonesia, Jamaica, Kazakhstan, Latvia, Lebanon, Mexico, Morocco, Pakistan, Panama, Peru, Philippines, Poland, Romania, Russia, El Salvador, South Africa, Thailand, Tunisia, Turkey, Ukraine, Uruguay, and Venezuela.

maturity, bid–ask spread, and amount and the same currency. The dispersion of changes in yield to maturity before the Lehman episode were relatively small (below 0.5%), and tripled following the Lehman episode.

FIGURE 4. EM-Bond Yields Following the Lehman Episode

(A) Average yield to maturities (B) Standard dev. of residual yield to maturities



Notes: Panel (A) shows the average daily change in yield to maturities for the EM bonds in our sample around the Lehman bankruptcy episode (September 15, 2008, $t = 0$). Panel (B) shows the standard deviation of the residuals from the empirical model $\Delta y_{it} = \alpha_{kst} + \alpha_{ct} + \gamma_t' Z_{it} + \varepsilon_{it}$, where Δy_{it} denotes the daily change in the log gross yield to maturity of bond i in period t, α_{kst} denotes a country of issuance by sector and time fixed effect, α_{ct} is a currency–time fixed effect, and Z_{it} is a vector of controls at the bond level including the bond's residual maturity, bid–ask spread, and outstanding amount. In Appendix C, we show that this empirical model can account for up to 98% of the variation in yields before the Lehman episode, and 80% of the variation after the Lehman episode. For details on the data, see Section 3.

Shares of EM bond holdings by global financial intermediaries. The most novel part of our data is that, 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, asset managers, holding companies, insurance companies, pension funds, and other financial institutions. We denote by θ_{ij} the share of bond i held by financial institution j as of 2008.q2. Within these holders, we focus on financial institutions publicly traded in DM stock exchanges, and thus containing data on their stock prices. Sixty-seven institutions meet our selection criteria. These institutions constitute our empirical measure of global banks. Appendix C lists these institutions and reports descriptive statistics for those with the largest EM bond holdings in our sample. As shown in the first column of Table 1, global financial intermediaries included in our sample held, on average, 46% of reported bond holdings at the end of 2008.q2, prior to the Lehman episode.

Change in global financial intermediaries' net worth per bond. We collect data on daily stock prices for each of the financial institutions, and compute the change in stock prices in a window around Lehman's bankruptcy. These data were obtained from Bloomberg and Datastream. Δe_j denotes financial institution j's change in log stock price ten days before and three days after September 15, 2008, the day when Lehman Brother's went bankrupt. The second column of Table 1 provides summary statistics of Δe_j, showing an average contraction in global financial intermediaries' net worth in the narrow window around the Lehman episode of 12%. Importantly, the cross-sectional standard deviation of this variable is 31%, suggesting enough variation in how global financial institutions were affected by the Lehman episode.

With data on bond holdings and stock prices, we compute a measure of the change in bond holders' average net worth around the Lehman episode, defined as $\Delta e_i = \sum_{j \in J} \theta_{ij} \Delta e_j$, where J denotes the set of global financial institutions with available data. This variable also displays significant cross-sectional variation, which we exploit in the empirical analysis.

3.3. *Identification and Empirical Model*

Our identification strategy to measure the effect of global financial institutions' net worth on EM bond spreads is based on exploiting price differences across bonds with similar default risk, maturity, and liquidity, but held by different financial institutions. We do so by estimating the set of regressions

$$\Delta_h y_i = \alpha_{ksh} + \alpha_{ch} + \beta_h \Delta e_i + \gamma_h' X_i + \varepsilon_{iks}, \tag{18}$$

where $\Delta_h y_i$ denotes the change in the log gross yield to maturity or price of bond i issued by country k in sector s between 10 days before the Lehman episode and h days after the episode; α_{ksh} denotes country (k) by sector (s) fixed effects; α_{ch} denotes currency fixed effects; X_i is a vector of controls at the bond level (including the total reported share $\sum_{j \in J} \theta_{ij}$, the bond's residual maturity, its bid–ask spread, its amount issued, and the average yield to maturity in the two months prior to the Lehman episode); and ε_i is a random error term. The coefficient of interest, β_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, to estimate the dynamic effects of global financial intermediaries' net worth on bond yields using Jorda's 2005 local projections.

Table 1. Global Financial Intermediaries' Net Worth during the Lehman Episode: Summary Statistics

	GFI coverage per bond	Δ Stock price GFI level	Δ Stock price bond level
Mean	46%	-12%	-12%
Median	45%	-6%	-8%
Std Deviation	25%	31%	17%
5th percentile	4%	-56%	-33%
95th percentile	94%	17%	4%
Num. Obs.	447	67	447

Notes: This table shows descriptive statistics for the change in global financial intermediaries' (GFIs) market value of net worth around Lehman's bankruptcy (ten days before and three days after September 15, 2008). The list of GFIs included in our sample is detailed in Appendix Table C4. The first column ($\sum_{j\in J}\theta_{ij}$) reports summary statistics of the shares held by these institutions for the EM bonds included in the sample. The second column (Δe_j) reports summary statistics of the change in GFIs' log stock prices with reported holdings of emerging-market bonds included in the sample. The last column summarizes the change in bond holders' average net worth around the Lehman episode, defined as $\sum_{j\in J}\theta_{ij}\Delta e_j/\sum_{j\in J}\theta_{ij}$.

Our identifying assumption is that, within EM bonds of a given country and sector and with a similar maturity, liquidity, and initial yield, no relevant factors driving changes in EM bond yields are correlated with the net worth of global financial intermediaries holding that bond. In this sense, focusing our analysis on a short window during the Lehman episode is useful for three reasons. First, during this episode global financial intermediaries experienced differential changes in their net worth that were primarily driven by factors related to events in developed markets (see, for example, Chodorow-Reich, 2013). Second, by focusing on a narrow window, we can exploit the price differences that arise for bonds of similar characteristics, as shown in Figure 4b. Third, as we show later, global financial intermediaries' exposure to risky EM debt in this period was small, which mitigates the concerns of reverse causality: a material change in net worth due to the changes in EM bond prices. The share of EM risky assets as a function of total risky assets in our sample of global financial institutions is 10% on average – see Table D1 – so the average contraction of 3% in EM bond prices during the narrow window considered should only have modest effects relative to the 12% average contraction in global financial intermediaries' net worth.[8]

The key idea of this identification strategy is that within an EM country–sector, and controlling for other bonds' relevant characteristics, bonds have similar default risk and liquidity properties but different holders. To further clarify by means of an example, our identification learns from the relative price dynamics of two foreign currency bonds issued by the Mexican government with similar maturities and liquidity, that therefore have the same default risk but are held by different global financial intermediaries.

3.4. *Empirical Results*

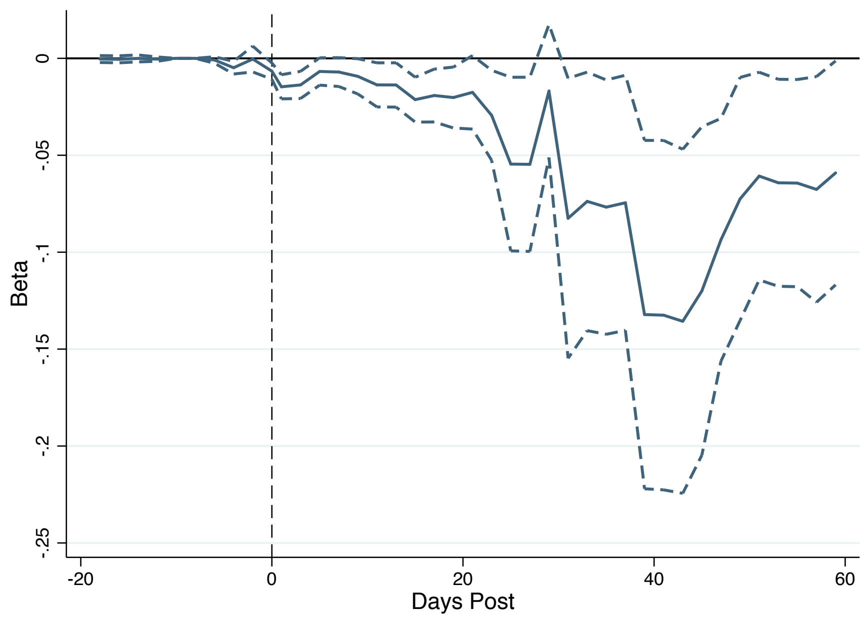
Figure 5 presents the results from estimating (18) on the bonds' yields to maturity at different horizons, h, ranging from 20 days prior to 60 days after the Lehman episode. Column (1) of Table 2 reports estimated coefficients and standard errors for the on-impact effect and the peak effect. Results indicate a negative estimated elasticity, β_h, indicating that bonds whose lenders' net worth contracted more during the Lehman episode experienced significantly higher yields to maturits in the two months after the episode. The estimated elasticity ranges from -0.01 to -0.14 and averages -0.058 in the two months after the Lehman episode. This indicates that a 1% lower lender net worth translates into 0.058% higher yields to maturity. 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 an increase in yields that is roughly 1.5 times as large as that of the average bond during the Lehman episode.

The fact that the point estimate of β_h is zero before the Lehman episode discards the presence of pretrends that can confound the empirical analysis. Additionally, the estimated effect of intermediaries' net worth on bond prices is temporary. The estimated elasticity begins to revert 45 days after the Lehman episode and ceases to be significantly different from zero two months after. As we argue in Appendix B, in the cross-section, temporary effects can be expected if financial intermediaries gradually arbitrage out excess returns for bonds with similar characteristics.

We perform a series of additional empirical analyses to argue that the empirical results are robust to alternative specifications and to mitigate potential concerns regarding our identification strategy. Table 2 presents the results of the most relevant alternative specifications. We relegate additional robustness analysis to Appendix C. Column (1) shows the on-impact and

[8] We also address the concern of reverse causality by instrumenting the change in global financial intermediaries' net worth. See the next subsection for more details.

Figure 5. The Effect of Global Financial Intermediaries' Net Worth on EM-Bond Yields



Notes: This figure shows the estimated elasticity of bonds' yields to maturity, β_h, to changes in the holder's net worth at horizon h from estimating the regression 18. Solid lines represent the point estimates of the regression at each horizon, and dotted lines are the 90%-confidence intervals.

peak effect of the baseline specification discussed above, which includes country–sector fixed effects, currency fixed effects, and residual maturity, bid–ask spread, amount outstanding, and initial yields as additional controls. Column (2) shows the same elasticities estimated from a model that includes fixed effects but excludes the additional bond-level controls. The point estimates of this specification are similar to those from the baseline specification.

Column (3) presents the results from estimating (18) using only sovereign bonds. Under this specification, country–sector fixed effects constitute borrower fixed effects, and the comparison of bonds with similar default risk is sharper. Results indicate a negative elasticity with a point estimate that is significant at the 5% level and is smaller (in absolute value) than the baseline. Column (4) shows the estimates of (18) using only similar maturities. We focus on bonds with a maturity date between 2010 and 2012. This specification provides a stronger control for maturities. Results show negative on-impact and peak effects, with the peak effect being larger (in absolute value) than the baseline effect.

Table 2. Effect of Global Financial Intermediaries' Net Worth on EM-Bond Yields: Regression Estimates

	Baseline	No Controls	Only Sov.	Same Maturity	IV
	(1)	(2)	(3)	(4)	(5)
Impact Effect	-0.013***	-0.013**	-0.008	-0.005	0.0026
	(0.004)	(0.006)	(0.005)	(0.017)	(0.011)
Peak Effect	-0.135**	-0.108**	-0.056**	-0.227***	-0.196***
	(0.053)	(0.048)	(0.023)	(0.076)	(0.055)
N Observations	402	447	198	70	108

Notes: This table shows the estimated elasticity of bonds' yields to maturity, β_h, to changes in the holder's net worth at two different horizons h, from estimating the regression 18. The on-impact effect corresponds to the estimated elasticity when the change in yields is computed from 10 days before to three days after Lehman's bankruptcy. The peak effect corresponds to the most negative estimated elasticity over all horizons before two months. Column (1) refers to the baseline estimation. Column (2) refers to the specification without maturity, bid–ask spread, amount, and initial yields as controls. Columns (3) and (4) refer to the baseline specification estimated using only sovereign bonds, and bonds that mature between 2010–2012, respectively. Column (5) refers to the specification in which the change in net worth is instrumented with the share of each bond held by AIG. Robust standard errors are in parentheses, and *, **, and *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

Finally, one concern is that the empirical estimates can capture direct effects that drops in EM bond prices around the Lehman episode can have on financial intermediaries' net worth because these bonds are part of their asset portfolios. As argued before, this concern is alleviated since the EM bonds constitute a small fraction of global financial intermediaries' asset portfolio. To strengthen this point, we also estimate the effect using the share of each bond that is held by AIG as of 2008.q2 as an instrument for the drop in the bond's holders net worth. AIG is a large financial institution that was severely hit during the Lehman episode due to its activities related to subprime securities, and that was a relevant holder of EM bonds.[9] By instrumenting the drop in the bonds' net worth with the share of those bonds held by AIG, we are isolating the

[9]Table C5 reports descriptive statistics about AIG in the EM debt market. AIG's stock price dropped by 88% during the narrow window around the Lehman episode. It was the financial institution with the largest drop in stock price among our sample of global financial intermediaries. Its stock crash was attributed to its large volume of activity providing insurance by issuing CDS on subprime mortgage-backed securities (see, for example, Harrington (2009)). AIG held more than 100 EM bonds, and its average share among lenders of these bonds was 9%. In the first stage of our IV strategy, $\Delta e_i = \alpha_{ksh} + \alpha_{ch} + \beta_{1S}\theta_i^{\mathrm{AIG}} + \gamma_h' X_i + \varepsilon_{iks}$ (where θ_i^{AIG}

effect that the bond prices could have had in financial intermediaries' net worth. Results, shown in the last column of Table 2, indicate a negative peak effect that is statistically significant and larger (in absolute value) than the baseline.

In Appendix C, we report additional complementary and robustness exercises regarding our estimation. We show that similar point estimates are obtained if we estimate the baseline specification (18) using only dollar-denominated bonds, if we only consider banks' change in stock price, and if we exclude market makers when computing the change in the stock price of the holders of each bond. We also show that results are insensitive to choosing a wider or tighter window around the Lehman episode to compute global financial intermediaries' change in stock price. Finally, we show that there is no selection of financial intermediaries into bonds with different maturities, liquidities, or amounts issued. We do document some degree of sorting of financial institutions with different changes in net worth into bonds issued by different countries and sectors, but these are the characteristics we can precisely control for with the use of country–sector fixed effects.

To summarize the findings of this empirical section, we exploit bond-level variation to document that well-identified shocks to global financial intermediaries' net worth have an impact on EM bond prices. This evidence is of interest on its own, as it supports the main mechanism highlighted in our model, through which global financial intermediaries' net worth is relevant for the pricing of EM debt. As shall be seen in the next section, we use our estimated elasticity to quantitatively discipline the degree of financial frictions that financial intermediaries face in our model.

4. Quantitative Analysis

In this section, we use our model and empirical evidence to study the relevance of global financial intermediaries for international lending. Section 4.1 discusses the model's calibration and its ability to account for observed international business-cycle patterns. Section 4.2 uses the calibrated model to quantify global banks' role in driving emerging markets' systemic debt crises and borrowing-cost fluctuations. Finally, Section 4.3 shows how financial intermediaries' portfolios and the distribution of bond positions in the world economy matter for the amplification of aggregate shocks.

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denotes the share of bond held by AIG in 2008.q2) the estimated coefficient $\hat{\beta}_{1S}$ is positive and statistically significat at the 0.1 percent level.

4.1. *Calibration and Quantitative Performance*

4.1.1. *Parametrization*

We discuss the calibration of the model by describing functional forms, parameter values, and the quantitative performance of the model in terms targeted and untargeted moments. In terms of solution method, our model's heterogeneity and aggregate uncertainty imply that the joint distribution of bond positions and output in the world economy, an infinite-dimensional object, is a state variable in agents' individual problems. We follow a Krusell and Smith (1998) type of approach to approximate the distribution of bond positions, combined with global methods for individual agents' problems, to solve the model's general equilibrium. We provide details of the numerical solution method in Appendix E.1.

In terms of functional forms, we assume EM households' period utility function includes constant relative risk aversion:

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

For the EMs' endowment processes, we assume AR(1) processes:

$$\ln y_{\text{EM}t} = \rho_{\text{EM}} \ln y_{\text{EM}t-1} + \sigma_{\text{EM}} \epsilon_{\text{EM}t}, \quad \epsilon_{\text{EM}t} \sim N(0,1),$$
$$\ln z_{it} = \rho_{\text{EM}} \ln z_{it-1} + \sigma_{\text{EM}} \epsilon_{it}, \quad \epsilon_{it} \sim N(0,1).$$

In this baseline calibration, we restrict the systemic and idiosyncratic component of output to have the same stochastic process (governed by ρ_{EM} and σ_{EM}) to study the differential effects of these shocks that arise due to endogenous amplification, rather than due to having different stochastic processes. In addition, in Appendix E.3.1, we study an alternative calibration in which we estimate different autoregressive and volatility parameters for the systemic and idiosyncratic processes of EM endowment and obtain similar results to those presented in this section. Similarly, to study the endogenous persistence of returns, we assume that the shock to the quality of capital follows an i.i.d. process, $\ln \omega_t = \sigma_\omega \epsilon_{\omega t}$, with $\epsilon_{\text{DM}t} \sim N(0,1)$, in our baseline calibration.[10]

Finally, we parametrize the output net of default costs by

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

where $d_0, d_1 \geq 0$. This or similar nonlinear functional forms, which lead to higher nonlinear default costs for higher values of y, are often used in the literature to rationalize the fact that

[10]This parametrization also delivers an autocorrelation of DM securities close to those observed in the data for U.S. high-yield bonds (a first-order autocorrelation coefficient of 0.2 in our period of analysis).

Table 3. Fixed Parameter Values

Parameter	Description	Value
γ	Risk aversion	2.00
θ	Reentry probability	0.25
ρ_{EM}	Systemic endowment, autocorrelation	0.68
σ_{EM}	Systemic endowment, shock volatility	0.03
β_{DM}	Discount rate of DM	0.98
α	Share of capital	0.35
δ	Depreciation	0.15
κ	Debt-to-asset ratio	4.50

Notes: This table shows the subset of parameters that are fixed in the calibration.

countries tend to default in bad times (e.g., Arellano, 2008; Chatterjee and Eyigungor, 2012; Aguiar et al., 2016).

We calibrate the model in two steps, by setting a subset of parameters to fixed values and another subset to match relevant EMs and global-bank moments. Table 3 describes the set of eight parameters we fix in the calibration. One period corresponds to one year. For parameters on preferences and technologies, we use standard values in the business-cycle literature: a coefficient of relative risk aversion for EMs, $\gamma = 2$; a discount factor for DM households, $\beta_{\text{DM}} = 0.98$, which implies an annual risk-free interest rate of 2%; a depreciation rate $\delta = 0.15$; and the share of capital, $\alpha = 0.35$. For the probability of reentering credit markets, we set $\theta = 0.25$ so that the average exclusion period is four years, in line with empirical evidence (Dias and Richmond, 2008; Gelos et al., 2011). For EMs' endowment process, we set $\rho_{\text{EM}} = 0.68$ and $\sigma_{\text{EM}} = 0.03$ to match the average autocorrelation and volatility of GDP in the sample of countries analyzed in Section 3 with available data. Finally, we set the parameter on financial intermediaries' borrowing constraint, $\kappa = 4.5$, based on the balance-sheet data of a set of 23 financial intermediaries included in the sample in our empirical Section 3, summarized in Table D1. Appendix E.3.2 shows the results for an alternative calibration of the model with $\kappa = 0$, which would correspond to asset managers being the global financial intermediary in the model.

We calibrate the remaining parameters of our model (Table 4) to match key EM and global-bank data moments, detailed in Table 5. The first group of moments are standard targets in the sovereign-debt literature that are particularly informative about EM discount factors

TABLE 4. Calibrated Parameter Values

Parameter	Description	Value
β_{EM}	Discount rate of EMs	0.90
d_0	Default cost — level	0.03
d_1	Default cost — curvature	14.0
σ	Bank survival rate	0.71
ϕ	Marginal cost of raising equity	4.00
η_{EM}	Mass of EM economies	2.16
σ_{DM}	Volatility of DM shock	0.065
$\bar{n}$	Net worth of new entrants	0.40
$\rho_{\text{DM,EM}}$	Correlation of exogenous shocks	0.55

Notes: This table shows the subset of parameters calibrated to match targeted moments detailed in Table 5.

(β_{EM}) and default costs (d_0, d_1), namely, the average EM external borrowing, the average EM default rate, and the correlation between EM-bond spreads and GDP. To compute these data moments, we use a sample of EMs with available data for the period 1994–2014. Appendix E.2 details the data sources. We target the observed average external-debt-to-GDP ratio of 15%, the average default frequency of 1.5%, and the average correlation between individual country's spreads and GDP of −31%. The remaining moments discipline parameters governing the role of global banks in the EM debt market. While each parameter can potentially affect all moments in the joint calibration, we find that the volatility of DM shocks, σ_ω, and the global banks' survival rate, σ, most affect the volatility of global banks' net worth and the volatility of EM-bond spreads. We target the observed volatility of EM-bond spreads of 170 basis points, and a volatility of global banks' market value of 28%, proxied by the cyclical fluctuations in the stock price of publicly traded U.S. banks, which have data coverage for the period of analysis (tracked by the XLF index). We also target the observed correlation between global banks' net worth and EMs' endowment of 35%, which is mostly governed by the correlation between EM and DM shocks, $\rho_{\text{DM,EM}}$. In our model, the average difference between the physical probability of default in EMs and their bond spreads is governed by average net worth in the system, linked to $\overline{n}$. We calibrate this parameter to target the average observed EM-bond spread of 410 basis points. The mass of EMs, μ_{EM}, particularly influences the share of EMs in global banks' portfolio of risky assets, which, as shall be seen later, is a key moment governing global banks' role in amplifying EM shocks. We measure this moment by combining data of individual banks' balance sheets in the sample of banks from our empirical section, with aggregate data on debt positions, obtaining a share of EMs in global banks' risky assets of 10%.[11] Section 4.3 studies alternative targets for this moment.

Finally, we discipline global banks' degree of financial frictions, governed by ϕ, by targeting an elasticity of EM-bond yields to changes in global banks' net worth following a DM shock of -0.06, which is the average of our empirical estimates in Section 3.4 in the two months after the Lehman episode.[12] As shown in Appendix Figure D1, this moment depends on the degree of financial frictions faced by global banks, governed by ϕ. In the absence of financial frictions ($\phi = 0$), the elasticity of EM-bond yields to global banks' net worth would be zero. As ϕ increases, so does the elasticity in absolute value. Our calibration targets this *conditional* elasticity estimated out of cross-sectional variation. Later in this section, we also show that this calibration strategy delivers an untargeted *unconditional* correlation between aggregate net worth and EM-bond spreads close to that observed in the data (-57%).

Furthermore, in Appendix B, we develop and solve an extension of the baseline model in which banks are heterogeneously affected by shocks and trade securities in secondary markets. This version of the model features the same source of variation as that used in the empirical analysis. We show that a quantitative version of that model, based on the same parameters used for the baseline model, can reproduce the empirical estimates from Section 3 when running an equivalent regression on model-simulated data. In this extension of the model, banks trade securities in secondary markets that feature trading frictions in the short run, which makes the net worth of the holders of each bond relevant for its pricing. In this environment, if banks face the same marginal cost of external finance in secondary and primary markets, the cross-sectional elasticity estimated in the data is tightly linked to the aggregate elasticity in the primary market, which is our main focus of interest.

[11] First, we use data on individual banks' balance sheets, which contain detailed information on the share of non-US government bonds for a large set of the banks used in our empirical analysis in the previous section. Appendix Table D1 details this share for the main banks of our sample for the year 2006. We then use data on aggregate external government debt from WEO to compute the share that corresponds to EM debt and to non-US DM debt. Combining these two figures we estimate an average share of EM debt in global banks' assets of 10%.

[12] In the model, to compute this elasticity, we conduct an impulse-response function on ω_t leading to a contraction of net worth of the same magnitude as that observed around the 2008 Lehman episode during the window considered in our empirical analysis. For more-detailed links between the model and the empirical analysis, see Appendix B.

Table 5. Targeted Moments

Target	Description	Data	Model
$\mathbb{E}[D_i/Y_i]$	Average EM debt	15.0%	14.0%
$\mathbb{P}[DF_i]$	EM default frequency	1.5%	1.8%
$\mathbb{E}[SP_i]$	Average EM-bond spreads	410bp	404bp
$\sigma(SP_i)$	Volatility EM-bond spreads	173bp	166bp
$\text{corr}(SP_i, \log Y_i)$	Correlation EM-bond spreads & endowment	−31%	−75%
$\sigma(\log V(N))$	Volatility global banks' net worth (NW)	0.28	0.25
$\text{corr}(\log V(N), \log Y_{\text{EM}})$	Correlation banks' NW & systemic EM endowment	35%	31%
$\mathbb{E}[A_{\text{EM}}/(A_{\text{EM}} + A_{\text{DM}})]$	Global banks' exposure to EMs	10%	10%
$\eta_{\text{EM,N}}$	Elasticity EM spreads to banks' NW	0.058	0.06

Notes: This table shows the set of data moments targeted in our calibration and their model counterparts, obtained by simulating a panel of countries from the calibrated model, and computing the average of individual countries' moments. The data moments regarding EM debt, default frequency, and bond spreads were computed using a sample of EMs with available data for the period 1994–2014. Appendix E.2 details the sample and data sources. The data moments on global banks' net worth were computed using the cyclical component in the stock price of publicly traded U.S. banks that have data coverage for the period of analysis (tracked by the XLF index). The share of global banks' exposure to EMs was measured by combining data of individual banks' balance sheets in the sample of banks from our empirical section (detailed in Appendix Table D1), with aggregate data on debt position (see footnote 11 for details). The elasticity of EM-bond spreads to global banks' net worth corresponds to the average of the empirical estimates in Section 3.4. See Section 4.1.1 and Appendix B for a detailed discussion of the model counterpart of this data object.

4.1.2. *Targeted and Untargeted Moments*

Table 5 shows that our model closely approximates most targeted moments. An exception is the countercyclicality of bond spreads, which our model overestimates relative to the data. However, this dimension of the calibration leads to overestimating the role of domestic factors driving default risk relative to the new mechanisms stressed in the paper.[13] Most of the parameter values of our baseline calibration, detailed in Table 4, are broadly aligned with those of the related literature. For instance, the discount factor and default costs are aligned with those in

[13]Our calibration does not perfectly match the targeted moments because our model is nonlinear. Matching more closely the countercyclicality of bond spreads can only be done at the expense of worsening the model performance in other key dimensions, such as the average debt position and default rates.

Aguiar et al. (2016). Our calibrated cost of external finance, ϕ, implies that the marginal cost of finance around the ergodic mean of equity issuance is around 10% (the mean value of $\frac{div}{n}$ is around 2.5% in simulated data from our model), which is aligned to that found in the corporate finance models estimated for nonfinancial U.S. firms (e.g., Hennessy and Whited, 2007). The survival rate of global banks is in the lower range of calibrated parameters in macro models with financial intermediaries (e.g., Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011; Perez, 2018), and together with $\overline{n}$, ensures that the net worth of the financial system is stationary given targeted average excess returns.

Tables 6 and 7 show that our calibrated model is also consistent with key untargeted moments regarding the international synchronization of EM debt prices and business-cycle moments. First, our model is consistent the large comovement within EM-bond spreads and between them and DM spreads documented in Section 3 and Longstaff et al. (2011). Table 6 shows that our model predicts an average correlation between an individual EM-bond spread and the average EM-bond spreads close to that observed in the data, and a high correlation between EM and DM spreads, although larger than that observed in the data for U.S. high-yield corporate bonds. Importantly, Table 6 shows that the model also predicts comovements between debt spreads and global banks' net worth quantitatively aligned to those observed in the data. This result means that, if we were to follow an alternative calibration strategy, targeting the *unconditional* correlation between global banks' net worth and EM-bond prices instead of our estimated elasticity in Section 3.4, we would obtain results similar to those in our current baseline calibration, which uses our empirical estimates.

Finally, our model is also consistent with key individual business-cycle patterns in emerging markets (see, for example, Neumeyer and Perri, 2005; Aguiar and Gopinath, 2007). In particular, Table 7 shows that 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 default likelihood.

Table 6. International Comovements: Data and Model

	Data	Model
Comovements in Debt Prices		
$\text{corr}(SP_{\text{EM}}, SP_{\text{EM,i}})$	0.69	0.71
$\text{corr}(SP_{\text{EM}}, SP_{\text{DM}})$	0.51	0.69
Comovement with Global Banks		
$\text{corr}(\log V(N), SP_{\text{EM}})$	-0.57	-0.59
$\text{corr}(\log V(N), SP_{\text{DM}})$	-0.79	-0.8

Notes: This table shows untargeted moments regarding international comovements and their model counterparts, obtained by simulating a panel of countries from the calibrated model. SP_{EM} refers to the average EM-bond spread, computed in the data using a sample of EMs with available data for the period 1994–2014. Appendix E.2 details the sample and data sources. $\text{corr}(SP_{\text{EM}}, SP_{\text{EM}i})$ refers to average correlation between the bond spread of an individual EM economy i and the average EM-bond spread. SP_{DM} refers to high-yield U.S. corporate bond spreads. $V(N)$ refers to the market value of global banks' net worth, proxied using the cyclical component in the stock price of publicly traded U.S. banks that have data coverage for the period of analysis (tracked by the XLF index).

Table 7. Individual EM Business Cycles: Data and Model

Target	Description	Data	Model
$\sigma(\log C_i)/\sigma(\log Y_i)$	Excess Volatility of Consumption	1.14	1.05
$\text{corr}(\log C_i, \log Y_i)$	Cyclicality of Consumption	0.90	0.96
$\sigma(TB_i/Y_i)$	Volatility of the Trade-Balance-to-Output Ratio	0.04	0.02
$\text{corr}(TB_i/Y_i, \log Y_i)$	Cyclicality of the Trade-Balance-to-Output Ratio	-0.31	-0.15

Notes: This table shows untargeted moments regarding individual EM business cycles and their model counterparts, obtained by simulating a panel of countries from the calibrated model and computing the average of individual countries' moments. C_i, Y_i, and TB_i/Y_i in the data refer, respectively, to consumption, GDP and the trade-balance-to-output ratio of a given country i. Moments were computed using a sample of EMs with available data for the period 1994–2014. Appendix E.2 details the sample and data sources.

4.2. *Global Banks' Relevance*

We now use our calibrated model to quantitatively assess global banks' role in the international transmission and amplification of shocks.

4.2.1. *Systemic Debt Crises*

We begin by focusing on the recent global financial crisis as an example of a systemic debt crises that affected borrowing economies in a synchronized fashion. Figure 6 shows that, during the 2007–2009 global financial crisis, the net worth of U.S. banks contracted by more than three standard deviations, and EMs' GDP contracted by more than two standard deviations. We study episodes of this nature in the model by analyzing the response to aggregate DM and EM shocks (ω_t and $y_{\text{EM}t}$) leading to a contraction in global banks' net worth and EMs' endowment of the magnitude observed in these data during 2007–2011. In particular, we consider the decrease in $y_{\text{EM}t}$ observed during 2007–2009, and a decrease in ω_t that generates a drop in global banks' net worth that is of the same magnitude as that observed in the data.

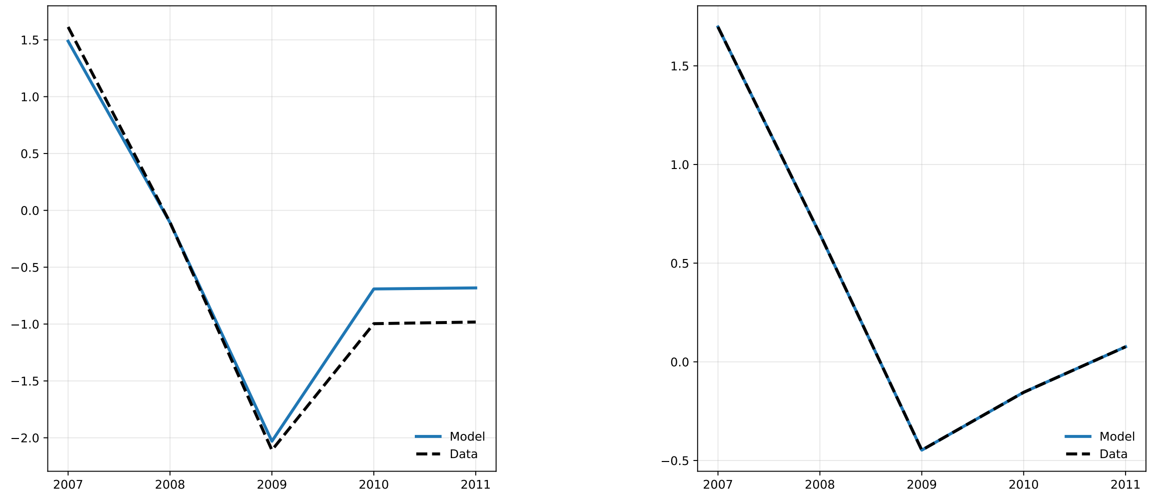
Figure 7 compares the dynamics of EM-bond spreads and consumption predicted in the model with those observed in the data during 2007–2011. In the data, during the 2007–2009 contraction, EM-bond spreads increased by 400 basis points (more than two standard deviations) and consumption adjusted by 1.5 standard deviations. The model predicts that, facing a contraction of global banks' net worth and EMs' systemic endowment of the magnitude observed in the data during 2007–2009, EM-bond spreads increase and consumption-experience adjustments aligned to those observed in the data.[14] In the model, spreads and consumption adjustment occur due to two forces. First, the lower realizations of returns in DM risky assets have 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. Higher costs of borrowing induce households to adjust consumption. 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 mechanisms in the dynamics of spreads and consumption adjustment during the global financial crisis. For this, we

[14] The model predicts an increase of bond spreads of 500 basis points and an adjustment of consumption of 2 standard deviations, both of which are larger than those observed in the data. A reason for the overprediction of adjustment in consumption in the model relative to the data might lie in the set of unconventional macroeconomic policies introduced worldwide during the global financial crisis (see, for example Catão et al., 2009).

FIGURE 6. Global Financial Crises: Aggregate Drivers

(A) Global Banks' Net Worth (B) EMs' Systemic Endowment



Notes: Global banks' net worth and EMs' systemic endowment were proxied, respectively, by the stock price of publicly traded U.S. banks (XLF index) and by the average GDP in a sample of EMs (detailed in Appendix E.2). *Data* objects in the figure (dashed black lines) refer to the cyclical components of these variables, expressed as deviations from a log-linear trend and standardized. *Model* objects in the figure (solid blue lines) refer to the dynamic response of global banks' net worth and EMs' systemic endowment to a sequence of shocks $\{\epsilon_{\omega t}, \epsilon_{\mathrm{EM}t}\}$ targeting the data objects during 2007–2011. The responses in the model were computed starting from the ergodic aggregate states. Variables in the model are expressed in log deviations from their ergodic means and standardized. The calibration of the model is detailed in Section 4.1.

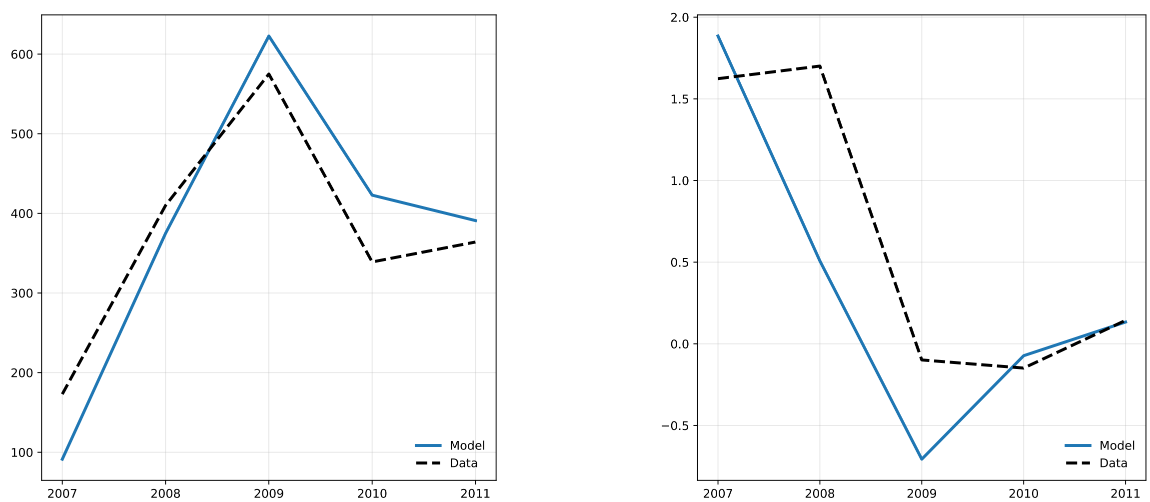
analyze spread and consumption dynamics predicted by the model in response to only a drop in ω and in response to only a drop in y_{EM}, of the magnitude analyzed in the 2007–2009 episode. Table 8 shows that more than two thirds of the increase in borrowing costs and a third of the consumption adjustment during the crisis can be explained by DM shocks, transmitted through global banks. Thus, global banks play an important role during systemic debt crises, which operates through transmitting DM shocks rather than amplifying EM-origin shocks. Section 4.3 analyzes in more detail how global banks' exposure and the distribution of bond positions can affect the role of banks amplifying EM-origin shocks.

4.2.2. *Decomposing Borrowing Costs*

The recent global financial crisis was characterized by a sharp decline in global banks' net worth. How relevant are global banks for regular business-cycle fluctuations? Table 9 conducts an unconditional decomposition of borrowing costs in EMs into their default- and risk-premium

Figure 7. EM-Bond Spreads and Consumption Dynamics During the Global Financial Crisis: Data and Model

(a) EM-Bond Spreads (b) EMs' Consumption Dynamics



Notes: Data objects in the figure (dashed black lines) refer to the average of sovereign-bond spreads and the cyclical component of consumption in a sample of EMs (detailed in Appendix E.2). EM-bond spreads are expressed in basis points. The cyclical component of consumption is expressed as deviations from a log-linear trend and standardized. *Model* objects in the figure (solid blue lines) refer to the dynamic response of EM-bond spreads and consumption to a sequence of shocks $\{\epsilon_{\omega t}, \epsilon_{\mathrm{EM}t}\}$, which targets the dynamics of global banks' net worth and EMs' systemic endowment during 2007–2011 (see Figure 7). The responses in the model were computed starting from the ergodic aggregate states. Consumption in the model is expressed in log deviations from its ergodic mean and standardized. The calibration of the model is detailed in Section 4.1.

components. We define the default-premium component of spreads as the bond spreads that would be observed, given EMs' equilibrium sequence repayment and borrowing policies, if debt were priced by a risk-neutral lender.[15] We define the risk premium as the difference between the spreads predicted by the model and the default-premium component.Table 9 shows that 27% of the average spreads and 40% of the fluctuations in spreads can be attributed to the risk-premium component. These figures are aligned with independent empirical estimates of the role of global factors for EM-bond spreads from the international-finance literature (e.g.,

[15]In particular, to compute the default-premium component of spreads, we compute a sequence of risk-neutral prices, $\tilde{q}^i_{\mathrm{EM}t} = \mathbb{E}_t \left[\beta_{\mathrm{DM}} \iota_{it+1} \left(1 + \xi \tilde{q}^i_{\mathrm{EM}t+1}\right)\right]$, where $\{\iota_{it}\}_{t=0}^{\infty}$ denotes the sequence of state-contingent repayment policies from our baseline economy. We then compute EM yields to maturity based on risk-neutral prices $\{\tilde{q}^i_{\mathrm{EM}t}\}_{t=0}^{\infty}$. Note that global banks still influence the default-premium component of spreads through EMs' default policies, which we take as given from the baseline model with global banks.

Table 8. Decomposing EM-Bond Spreads and Consumption Dynamics During the Global Financial Crisis

	ΔY_{EM}	ΔNW	Δ Spread	Δ C
Data	-2.14	-3.72	402	-1.72
Model				
Joint Shocks	-2.14	-3.52	531	-2.59
EM Shock Only	-2.14	-0.09	121	-1.55
DM Shock Only	0.0	-3.36	351	-0.92

Notes: Data figures (first line) correspond to the dynamics of variables of interest observed during the 2007–2009 period. ΔY_{EM} and ΔC refer to the change in the average cyclical component of GDP and consumption, respectively, in a sample of EMs (detailed in Appendix E.2) between 2009 and 2007. Cyclical components were computed with respect to a log-linear trend and standardized. ΔSpread refers to the change in the average of sovereign-bond spreads for the same sample of EM countries, in basis points. ΔNW corresponds to the change in the cyclical component of the market value of global banks' net worth, proxied by the stock price of publicly traded U.S. banks (XLF index), computed with respect to a log-linear trend and standardized. *Model* figures (lines 2–4) correspond to experiments in the calibrated model (detailed in Section 4.1), aimed at decomposing of the dynamics of EM-bond spreads and consumption during an episode targeted to match the aggregate drivers of the 2007–2009 global financial crisis. All variables in the model are expressed in the same units as in the data. *Joint Shocks* (line 2) corresponds to the dynamic response in the model to a sequence of shocks $\{\epsilon_{\omega t}, \epsilon_{\text{EM}t}\}$ that targets the dynamics of global banks' net worth and EMs' systemic endowment during 2007–2011 (see Figure 7). The responses in the model were computed starting from the ergodic aggregate states. *EM shocks only* and *DM shocks only* (lines 3 and 4) correspond, respectively, to the response predicted in the model to just the sequence of shocks $\epsilon_{\text{EM}t}$ from the previous exercise and to just the sequence of $\epsilon_{\omega t}$ shocks from the previous exercise.

Longstaff et al., 2011), and suggest that global banks play a key role driving these global factors. Moreover, global banks' role, driving more than half of the fluctuations in EMs' spreads, suggests that the proposed model can provide a microfoundation for exogenous fluctuations in external borrowing costs, which have been identified as key drivers of EM consumption, output, and exchange-rate dynamics (e.g., Neumeyer and Perri, 2005; García-Cicco et al., 2010). In Appendix E.3.3 we show how the unconditional decomposition of spreads change for different values of ϕ, highlighting the fact that financial frictions drive the role of global banks in the determination of sovereign spreads.

TABLE 9. Unconditional Decomposition of EM-Bond Spreads

	Average	Std Dev
Data	410	173
Model	404	166
Default Premium	295	137
Risk Premium	109	91

Notes: This table shows a decomposition of EM-bond spreads predicted by the model into their default- and risk-premium components. We define the default-premium component of spreads as the bond spreads that would be observed, given EMs' equilibrium sequence repayment and borrowing policies, if debt were priced by a risk-neutral lender. To compute the default-premium component of spreads, we compute a sequence of risk-neutral prices, $\tilde{q}^i_{\mathrm{EM}t} = \mathbb{E}_t\left[\beta_{\mathrm{DM}}\iota_{it+1}\left(1+\xi\tilde{q}^i_{\mathrm{EM}t+1}\right)\right]$, where $\{\iota_{it}\}_{t=0}^{\infty}$ denotes the sequence of state-contingent repayment policies from our baseline economy. We then compute EM yields to maturity based on risk-neutral prices $\{\tilde{q}^i_{\mathrm{EM}t}\}_{t=0}^{\infty}$. We define the risk premium as the difference between the spreads predicted by the model and the default-premium component. The first column shows the unconditional average of each variable and the second column the unconditional volatility. The calibration of the model is detailed in Section 4.1.

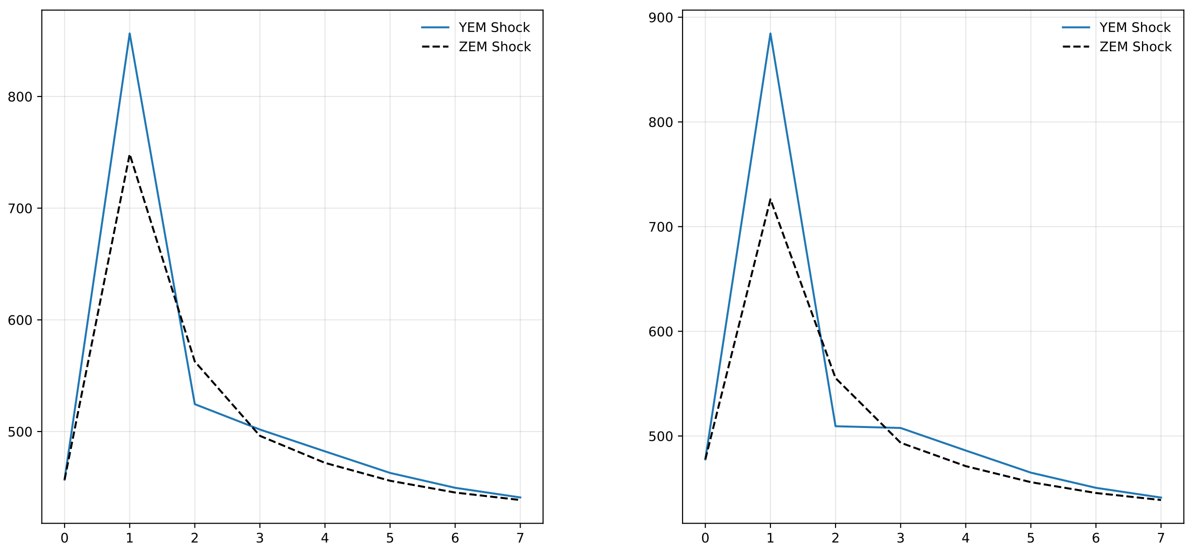
4.3. *The Role of Financial Intermediaries' Portfolios and the Distribution of Bond Holdings*

So far our quantitative model has focused on a calibration in which, as currently observed in the data, global banks' exposure to EMs in their portfolio of risky securities is relatively low (10%). However, as the literature on the history of debt crises suggests, low exposure is not always the rule. For instance, Appendix Table D2 shows that in the Latin American debt crisis of 1980s, U.S. banks' exposure to EMs' debt was three times their current exposure. We now study the predictions of the model for a calibration of the model in which global banks' exposure to EM debt is 35%, closer to that observed in the 1980s. We refer to this calibration as a *high-exposure* economy, and to our baseline calibration as a *low-exposure* economy.

Figure 8a shows that in a high-exposure economy, EMs' borrowing costs respond significantly more to EM systemic endowment shocks than to idiosyncratic endowment shocks.[16] This is because negative systemic shocks lead to EM default, which contracts global banks' net worth,

[16]In particular, we analyze the impulse-response of equal-magnitude negative shocks to the systemic and idiosyncratic components of output. To compute the responses to a shock to the systemic (idiosyncratic) component of output, we analyze the economy starting from the average aggregate states from its ergodic distribution and feed in an negative shock of the same magnitude to each component of output, and then trace the dynamics of the variables of interest.

Figure 8. Amplification with High Exposure



(A) Ergodic Dispersion of EM Debt

(B) High Dispersion of EM Debt

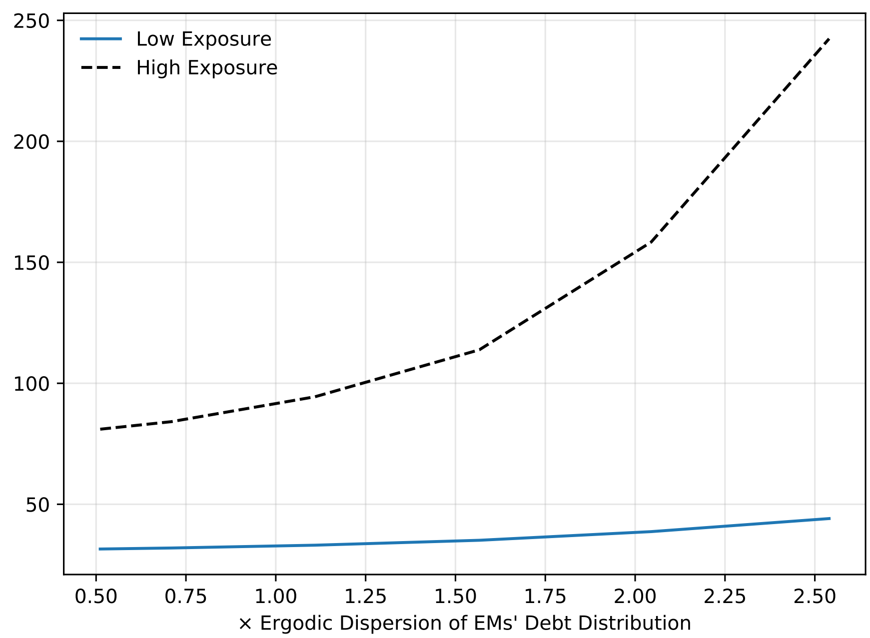
Notes: These figures show the dynamics of spreads following a two-s.d. shock to the systemic and idiosyncratic endowment, when global banks' exposure to EMs is 35%. The left panel shows the case where the initial distribution is the ergodic distribution, while the right panel starts with a distribution with twice its dispersion. Spreads are expressed in basis points. The blue solid line shows the reaction of spreads to the systemic endowment and the black dashed line shows the reaction to an idiosyncratic endowment shock.

contracting the global supply funds, and further increasing the returns to EMs. Appendix Figure D2 shows that, in our baseline calibration, this effect is relatively small, as low exposure attenuates the effect of lower EM debt prices on global banks' net worth.

We further argue that the degree of amplification is also influenced by the distribution of debt positions in the economy. To illustrate this, we replicate the same impulse-response analysis starting from an initial distribution of debt positions with a cross-sectional standard deviation that is twice as large as the average standard deviation from the ergodic distribution.[17] Figure 8b shows the differential reaction of spreads to an idiosyncratic and systemic output shock. In this case, the amplification is roughly 50% larger than starting from the ergodic dispersion. The reason is that when debt positions are more dispersed, a systemic output drop increases default risk for those heavily indebted economies, which are a larger fraction and, hence, create a larger drop in global banks' net worth. Finally, Figure 9 shows that this differential amplification holds

[17] A standard deviation that is twice as large is empirically plausible. Both in the data and in model simulations, the standard deviation fluctuates to reach levels that are twice as large as the average.

Figure 9. Amplification of Shocks: The Role of Global Banks' Portfolios and the Distribution of EM Debt



Notes: This figure shows the difference between the response of EM bond spreads to a systemic endowment shock and an idiosyncratic endowment shock for different initial distributions and different EM exposures. In particular, each point of the solid blue line corresponds to the difference between the impact response of EM spreads to a two-s.d. shock to the systemic component of endowment and to a two-s.d. shock to the idiosyncratic component of endowment in the baseline calibration for different dispersions of the initial distribution. Each point in the dashed black line shows a similar object for the economy calibrated to global banks' 35% exposure to EMs.

globally for multiple parametrizations of the debt-distribution dispersion. It also shows that banks must be more heavily exposed to EM debt to generate this differential amplification. This last exercise identifies that two key variables, banks' exposure to EM debt and the dispersion in the debt distribution, are relevant in determining the transmission and amplification of aggregate shocks in the world economy.

5. Conclusions

In this paper, we studied the long-held view in policy circles that global financial intermediaries are central actors shaping systemic debt crises. We did so by combining new empirical evidence and a quantitative model of the world economy with heterogeneous borrowers and financial intermediaries. Our empirical evidence shows that emerging-market bond prices are affected by changes in net worth of the global financial intermediaries holding these bonds. Our model shows that this evidence can be interpreted as driven by financial frictions faced by intermediaries investing in emerging-market debt, and our quantitative study of how these frictions give rise to a key role for financial intermediaries driving fluctuations in borrowing costs and consumption in emerging-market economies, both during debt crises and in regular business cycles.

Our findings stress the lender side of systemic debt crises and episodes of large external borrowing and consumption adjustments (or *sudden stops*). From the perspective of individual borrowing economies, lenders' dynamics manifest themselves as fluctuations in external borrowing costs, which have a long tradition in international macroeconomics. However, for policymakers operating in the world economy, a detailed framework such a the one constructed in this paper can help understand the nature of these fluctuations. In this sense, the paper's findings highlight the importance of measuring global financial intermediaries' portfolios and the distribution of debt positions in the global economy in detail to assess potential global risks. We leave a more detailed policy analysis based on this framework for future research.

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Appendix A. Theoretical Framework: Further Details and Extensions

A.1. *Recursive Model Representation*

This section provides a recursive representation of the model global economy developed in Section 2, and presents some results on the characterization of equilibrium allocations. The timing is as follows.

i. At the beginning of each period, the exogenous idiosyncratic and aggregate shocks $(z_i, y_{\text{EM}}, \omega)$ are realized. An individual bank enters the period with book value of net worth n and market value $v(\mathbf{s}, n)$. The aggregate state is given by $\mathbf{s} \equiv \{\mathbf{s}_x, \Delta\}$, where $\mathbf{s}_x \equiv \{y_{\text{EM}}, \omega\}$, $\Delta \equiv \{A_{\text{DM}}, D, g(b,z)\}$, and $g(b,z)$ is the joint distribution of debt and idiosyncratic output of EMs that borrowed in the previous period.
ii. Exit shocks are realized. Assets are repaid, banks can issue new deposits.
iii. Banks can issue new equity and purchase new EM and DM assets in primary markets.

Global Banks' Recursive Problem. The market value of a global bank is given by

$$v(\mathbf{s}, n) = \max_{\substack{\{a'_{\text{EM},(b,z)} \geq 0\}, \\ a'_{\text{DM}} \geq 0, d', div}} (1-\sigma)n + \sigma \left(div(1 + \mathbb{I}_{div<0}\mathcal{C}(div, n)) + \beta_{\text{DM}} \mathbb{E}\left[v(\mathbf{s}', n')\right] \right), \tag{19}$$

subject to

$$\int\int_{(b,z):g_+(b,z)>0} q_{\text{EM},(b,z)}(\mathbf{s}) a'_{\text{EM},(b,z)} \, \mathrm{d}b \, \mathrm{d}z + q_{\text{DM}}(\mathbf{s}) a'_{\text{DM}} = n + d' - div,$$

$$d' \leq \kappa n,$$

$$n' = \int\int_{(b,z):g_+(b,z)>0} \iota_{\text{EM},(b,z)}(\mathbf{s}') \left(1 + \xi q_{\text{EM},(b,z)}(\mathbf{s}')\right) a'_{\text{EM},(b,z)} \, \mathrm{d}b \, \mathrm{d}z + \omega' \left(\alpha A_{\text{DM}}^{\alpha-1} + 1 - \delta\right) a'_{\text{DM}} - R_d d'.$$

where d' denotes the choice of deposits, div denotes dividend payments from banks that did not exit; $a'_{\text{EM},(b,z)}$ denotes the mass of securities from economies with borrowing b and idiosyncratic income z, a'_{DM} the mass of nonfinancial DM securities purchased, and $q_{\text{EM},(b,z)}(\mathbf{s})$ and $q_{\text{DM}}(\mathbf{s})$ their respective prices; and $\iota_{\text{EM},(b,z)}(\mathbf{s})$ denotes EMs' repayment policies.

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

$$V(b, z, \mathbf{s}) = \max_{\iota} \iota V^{\text{r}}(b, z, \mathbf{s}) + (1-\iota) V^{\text{d}}(z, \mathbf{s}), \tag{20}$$

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

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

$$V^{\mathrm{r}}(b, z, \mathbf{s}) = \max_{b'} u(c) + \beta \mathbb{E}\left[V(b', z', \mathbf{s}')\right], \tag{21}$$

$$\text{s.t. } c = y_{\mathrm{EM}} + z + q(b', z, \mathbf{s})(b' - \xi b) - b, \tag{22}$$

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

where $\mathbf{s}' = \Gamma(\mathbf{s}, \mathbf{s}'_x, \hat{A}_{\mathrm{DM}}(\mathbf{s}), \hat{D}(\mathbf{s}), \hat{b}'(b, z, \mathbf{s}))$ is the law of motion of the aggregate state $\mathbf{s}'$, and $\hat{A}_{\mathrm{DM}}(\cdot)$, $\hat{D}(\cdot)$, and $\hat{b}'(\cdot)$ denote perceived policies at the borrowing stage describing, respectively, aggregate DM assets, bank 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.

Finally, the value of default is given by

$$V^{\mathrm{d}}(z, \mathbf{s}) = u(c) + \beta \mathbb{E}\left[\theta V^{\mathrm{r}}(0, z', \mathbf{s}') + (1 - \theta) V^{\mathrm{d}}(z', \mathbf{s}')\right], \tag{23}$$

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

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

Equilibrium Definition. We can now define a recursive equilibrium.

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

(1) Given prices, laws of motion, and perceived policies, global banks' policies and value functions solve their recursive problem (19).

(2) Given prices, laws of motion, and perceived policies, borrowers' policies and value functions solve their recursive problem (20)–(23).

(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 global banks' optimal choices.

Proposition **2.** *Any equilibrium with positive aggregate holdings of all risky assets must have*

$$\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{EM},(b,z)}(\mathbf{s}',\mathbf{s})\right] = \mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right], \tag{24}$$

where returns on EMs, $R_{\text{EM},(b,z)}(\mathbf{s}',\mathbf{s})$, and DM economies, $R_{\text{DM}}(\mathbf{s}',\mathbf{s})$, are defined as

$$R_{\text{DM}}(\mathbf{s}',\mathbf{s}) = \frac{\omega'\left(\alpha A_{\text{DM}}^{\alpha-1} + 1 - \delta\right)}{q_{\text{DM}}(\mathbf{s})} \text{ and}$$
$$R_{\text{EM},(b,z)}(\mathbf{s}',\mathbf{s}) = \frac{\iota_{\text{EM},(b,z)}(\mathbf{s}')\left(1 + \xi q_{\text{EM},(b,z)}(\mathbf{s}')\right)}{q_{\text{EM},(b,z)}(\mathbf{s})}.$$

Additionally, global banks' value function is linear in their book value of net worth:

$$v(\mathbf{s},n) = \nu(\mathbf{s})n, \tag{25}$$

where the marginal value of net worth solves the recursive equation

$$\nu(\mathbf{s}) = (1-\sigma) + \sigma\left(\frac{1}{4\phi}\left(\beta_{\text{DM}}\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right] - 1\right)^2 \right.$$
$$\left. + \beta_{\text{DM}}\left(\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right](1+\kappa) - \mathbb{E}\left[\nu(\mathbf{s}')\right]R_d\kappa\right)\right). \tag{26}$$

Proof. We proceed by guessing linearity of the value function and verifying the conjecture. Start by conjecturing linearity of the banks' problem: $v(\mathbf{s},n) = \nu(\mathbf{s})n$. Then

$$v(\mathbf{s},n) = \max_{\substack{\{a'_{\text{EM},(b,z)}\geq 0\} \\ a'_{\text{DM}}\geq 0, d', div}} (1-\sigma)n + \sigma div(1 + \mathbb{I}_{div<0}\mathcal{C}(div,n))$$
$$+ \sigma\beta_{\text{DM}}\mathbb{E}\left[\nu(\mathbf{s}')\left(\iint_{(b,z):g_+(b,z)>0} R_{\text{EM},(b,z)}(\mathbf{s}',\mathbf{s})q_{\text{EM},(b,z)}(\mathbf{s})a'_{\text{EM},(b,z)}\,\mathrm{d}b\,\mathrm{d}z \right.\right.$$
$$\left.\left. + R_{\text{DM}}(\mathbf{s}',\mathbf{s})q_{\text{DM}}(\mathbf{s})a'_{\text{DM}} - R_d d'\right)\right] \tag{27}$$

subject to

$$\int\int_{(b,z):g_+(b,z)>0} q_{\text{EM},(b,z)}(\mathbf{s})a'_{\text{EM},(b,z)}\,\mathrm{d}b\,\mathrm{d}z + q_{\text{DM}}(\mathbf{s})a'_{\text{DM}}\,\mathrm{d}j = n - div + d',$$
$$d' \leq \kappa n$$

A sufficient condition for the borrowing constraint to be binding is

$$\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right] > \mathbb{E}\left[\nu(\mathbf{s}')R_d\right].$$

In any asset b, z with positive investments,

$$\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{EM},(b,z)}(\mathbf{s}',\mathbf{s})\right] = \mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right]. \tag{28}$$

Substituting in the objective function,

$$
\begin{aligned}
v(\mathbf{s},n) = (1-\sigma)n + \sigma div(1+\mathbb{I}_{div<0}\mathcal{C}(div,n)) \\
+ \sigma\beta_{\text{DM}}\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right]\left(\int\int_{(b,z):g_+(b,z)>0} q_{\text{EM},(b,z)}(\mathbf{s})a'_{\text{EM},(b,z)}\,\mathrm{d}b\,\mathrm{d}z + q_{\text{DM}}(\mathbf{s})a'_{\text{DM}}\right) \\
- \sigma\beta_{\text{DM}}\mathbb{E}\left[\nu(\mathbf{s}')\right]R_d\kappa n, \quad (29)
\end{aligned}
$$

and substituting in balance-sheet equation,

$$
\begin{aligned}
v(\mathbf{s},n) = (1-\sigma)n + \sigma div(1+\mathbb{I}_{div<0}\mathcal{C}(div,n)) \\
+ \sigma\beta_{\text{DM}}\left(\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right](n(1+\kappa)-div) - \mathbb{E}\left[\nu(\mathbf{s}')\right]R_d\kappa n\right). \quad (30)
\end{aligned}
$$

Taking first order condition with respect to div,

$$
1+\mathcal{C}(div,n)+div\mathcal{C}_{div}(div,n) = \beta_{\text{DM}}\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right]. \quad (31)
$$

Under the assumed $\mathcal{C}(div,n) = \phi\left(\frac{-div}{n}\right)$, we get

$$
\begin{aligned}
v(\mathbf{s},n) = (1-\sigma)n + \sigma\Bigg\{-\frac{1}{2\phi}(\beta_{\text{DM}}\mathbb{E}[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})]-1)n\Bigg(1+\frac{1}{2}(\beta_{\text{DM}}\mathbb{E}[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})]-1)\Bigg) \\
+\beta_{\text{DM}}\Bigg(\mathbb{E}[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})]\Bigg((1+\kappa)n+\frac{1}{2\phi}(\beta_{\text{DM}}\mathbb{E}[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})]-1)n\Bigg)\Bigg) - \mathbb{E}[\nu(\mathbf{s}')]R_d\kappa n\Bigg\} \quad (32)
\end{aligned}
$$

or, equivalently,

$$
\begin{aligned}
v(\mathbf{s},n) = (1-\sigma)n + \sigma\Bigg(\frac{1}{4\phi}\left(\beta_{\text{DM}}\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right]-1\right)^2 n \\
+\beta_{\text{DM}}\left(\mathbb{E}\left[\nu(\mathbf{s}')R_{\text{DM}}(\mathbf{s}',\mathbf{s})\right](1+\kappa) - \mathbb{E}\left[\nu(\mathbf{s}')\right]R_d\kappa\right)n. \quad (33)
\end{aligned}
$$

This confirms linearity of net worth with $v(\mathbf{s},n) = \nu(\mathbf{s})n$. □

Appendix B. Model with Secondary Markets

In this Appendix, we develop and solve an extension of the baseline model in which we allow for trading of securities in secondary markets. This version of the model features the same source of variation as in the empirical analysis. We show that a quantitative parametrization of the model that closely matches that of the baseline can reproduce the same empirical estimates as those in the data.

B.1. *Model*

There are two main differences with the baseline model. First, each period contains two subperiods: a first subperiod, in which securities are traded in secondary markets, and a second subperiod, in which securities are traded in primary markets. In particular, 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 with each other in secondary markets. Then risky securities are repaid, banks repay outstanding deposits, and can issue new deposits, pay dividends or raise equity, and purchase newly issued risky securities in primary markets.

The second difference is that each EM economy issues different varieties of bonds, indexed by ℓ, that have the same repayment but will feature different holders in equilibrium. We assume that banks specialize in a particular variety and trade securities of that variety issued by any EM.[18] These two additions allow the model to feature the variation found in the empirical analysis, namely, multiple bonds issued by the same borrower with different holders.

As in the baseline model, global banks' objective is to maximize the lifetime discounted payouts transferred to DM households,

$$\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta_{\text{DM}}^{s-t} \pi_{jt+s}. \tag{34}$$

A bank j that specializes in variety ℓ arrives at the period t secondary market with a portfolio of EM securities $\{a^i_{\text{EM}jt-1}(\ell)\}_{i\in\mathcal{I}_{t-1}}$, DM securities $a_{\text{DM}jt-1}(\ell)$, and deposits d_{jt-1}, acquired in the primary market at $t-1$. Secondary markets are segmented by variety: Banks can only trade

[18] This specialization is introduced to generate dispersion in banks' portfolios of securities, as we observe in the data. It can capture the reasons for why banks tend to have large holdings of specific bonds by a borrower, as opposed to smaller holdings of all securities issued by a particular borrower. The presence of fixed costs of trading each security can give rise to this type of specialization. Additionally, this specialization could also occur if we don't restrict banks to buy a particular security, because, in equilibrium, the portfolio of individual banks is undetermined given that banks are indifferent between purchasing all risky securities in primary markets.

with others that specialize in the same variety at prices $\{q^{i0}_{\text{EM}jt}(\ell)\}_{i\in\mathcal{I}_t}$ for EM securities and $q^0_{\text{DM}jt}(\ell)$ for DM securities. This implies that the index ℓ denotes both a particular variety of EM security, *and* a particular trading network (hence, the dependence of $q^0_{\text{DM}jt}(\ell)$ on ℓ).[19] The value of the net worth in the secondary market is given by

$$n^0_{jt} = \int_{i\in\mathcal{I}_{t-1}} q^{i0}_{\text{EM}t}(\ell)a^i_{\text{EM}jt-1}(\ell)\,\mathrm{d}i + q^0_{\text{DM}t}(\ell)a_{\text{DM}jt-1} - R_d d_{jt-1}. \tag{35}$$

In the secondary market, banks can purchase existing securities $(a^0_{\text{DM}jt}, \{a^{i0}_{\text{EM}jt}(\ell)\}_{i\in\mathcal{I}_{t-1}})$, issue equity div^0_{jt}, and issue new deposits d^0_{jt} to be repaid in the period t primary market. Their balance-sheet constraint in the secondary market is given by

$$n^0_{jt} + d^0_{jt} = \int_{i\in\mathcal{I}_t} q^{i0}_{\text{EM}t}(\ell)a^{i0}_{\text{EM}jt}(\ell)\,\mathrm{d}i + q^0_{\text{DM}t}(\ell)a^0_{\text{DM}jt} + div^0_{jt}. \tag{36}$$

A bank arrives at the primary market with the portfolio of securities and liabilities issued in the secondary market and a net worth given by repayment associated with each of these securities

$$n_{jt} = \int_{i\in\mathcal{I}_{t-1}} R^{i0}_{\text{EM}t}(\ell)q^{i0}_{\text{EM}t}(\ell)a^{i0}_{\text{EM}jt}(\ell)\,\mathrm{d}i + R^0_{\text{DM}t}(\ell)q^0_{\text{DM}t}(\ell)a_{\text{DM}jt} - R^0_d d^0_{jt}, \tag{37}$$

where $\left(\{R^{i0}_{\text{EM}t}(\ell)\}_{i\in\mathcal{I}_{t-1}}, R^0_{\text{DM}t}(\ell)\right)$ are the returns from holding EM and DM securities in period t, from the secondary market of trading network ℓ until the primary market subperiod, and R^0_d the rate on deposits from the secondary to primary markets. In the primary market, banks face a similar choice problem as in the secondary market: Each bank can purchase new securities $(a_{\text{DM}jt}, \{a^i_{\text{EM}jt}(\ell)\}_{i\in\mathcal{I}_{t-1}})$, issue equity div_{jt}, and issue new deposits d_{jt} to be repaid in the period $t+1$ secondary market. Its balance-sheet constraint in the primary market is given by

$$n_{jt} + d_{jt} = \int_{i\in\mathcal{I}_t} q^i_{\text{EM}t}(\ell)a^i_{\text{EM}jt}(\ell)\,\mathrm{d}i + q_{\text{DM}t}a_{\text{DM}jt} + div_{jt}. \tag{38}$$

Banks face the same frictions to finance their investments in both primary and secondary markets. They face borrowing constraints,

$$\kappa d^0_{jt} \le n^0_{jt} \quad \text{and} \quad \kappa d_{jt} \le n_{jt} \tag{39}$$

and a cost of $\mathcal{C}(div, n) = \phi\left(\frac{-div}{n}\right)$ per unit of equity raised in the primary market, and $\mathcal{C}(div^0, n^0) = \phi\left(\frac{-div^0}{n^0}\right)$ per unit of equity raised in the secondary market. The net payouts to DM households are

$$\pi_{jt} = div^0_{jt}(1 + \mathbb{I}_{div^0_{jt}<0}\mathcal{C}(div^0_{jt}, n^0_{jt})) + div_{jt}(1 + \mathbb{I}_{div_{jt}<0}\mathcal{C}(div_{jt}, n_{jt})). \tag{40}$$

[19] We use the same notation as in the baseline model, and explain the new notation as it is introduced. We refer to variables in the secondary market with the 0 superscript.

Finally, each subperiod experiences an i.i.d. exit shock which occurs with probability $1-\sigma$. Banks that exit repay outstanding deposits, sell their securities in the relevant market, and transfer the net proceedings to their owners. Each subperiod, a mass of $(1-\sigma)$ new banks enter the economy, so that the total mass of global banks is always fixed at one. The new entrants are endowed with units of the final good $\overline{n}$ and $\overline{n}^0$ in the primary market and secondary market, respectively.

The problem of global bank j specializing in variety ℓ is to choose state-contingent plans $\{((a^{i0}_{\text{EM}jt}(\ell), a^{i}_{\text{EM}jt+1}(\ell))_{i\in[0,\eta_{\text{EM}}]}, a^0_{\text{DM}jt},\ a_{\text{DM}jt}, div^0_{jt}, div_{jt}, d^0_{jt}, d_{jt})\}_{t=0}^{\infty}$ to maximize (8) subject to flow of funds and financial constraints (35)–(40). The bank's problem is characterized by asset-pricing conditions for the secondary and primary market:

$$R^{i0}_{\text{EM}t}(\ell) = R^0_{\text{DM}t}(\ell), \tag{41}$$

$$\mathbb{E}\left[\nu^0_{t+1}(\ell)\frac{q^{i0}_{\text{EM}t+1}(\ell)}{q^{i}_{\text{EM}t}(\ell)}\right] = \mathbb{E}\left[\nu^0_{t+1}(\ell)\frac{q^{0}_{\text{DM}t+1}(\ell)}{q_{\text{DM}t}(\ell)}\right] \equiv R^e_t(\ell), \tag{42}$$

for all ℓ and securities i with positive investments, where $\nu^0_{t+1}(\ell)$ is the marginal value of net worth of a bank specializing in variety ℓ in secondary markets of period $t+1$.[20] The first equation states that required returns from holding any security of a given variety from secondary or primary markets are the same.[21] Similarly, the second equation states that required returns from holding any security of a given variety from primary markets of period t to secondary markets of period $t+1$ are the same. The optimal choices of financing by binding borrowing constraints (39) and equity choices given by[22]

$$-2\phi\left(\frac{div_{jt}}{n_{jt}}\right) = \beta_{\text{DM}}R^e_t(\ell) - 1 \quad \text{and} \quad -2\phi\left(\frac{div^0_{jt}}{n^0_{jt}}\right) = \nu^0_t R^0_{\text{DM}t}(\ell) - 1. \tag{43}$$

In both primary and secondary markets, higher required returns lead to larger equity issuance.

[20]The marginal value of net worth in the secondary market, $\nu^0_{t+1}(\ell)$, and in the primary market, ν_{t+1}, satisfy two difference equations:

$$\nu^0_t(\ell) = (1-\sigma) + \sigma\left(\frac{1}{4\phi}(\nu_t R^0_{\text{DM}t}(\ell)-1)^2 + \nu_t R^0_{\text{DM}t}(\ell)(1+\kappa) - \nu_t R^0_d\kappa\right),$$

$$\nu_t = (1-\sigma) + \sigma\left(\frac{1}{4\phi}\left(\beta_{\text{DM}}\mathbb{E}\left[\nu^0_{t+1}(\ell)\frac{q^0_{\text{DM}t+1}(\ell)}{q_{\text{DM}t}(\mathbf{s})}\right]-1\right)^2 + \beta_{\text{DM}}\left(\mathbb{E}\left[\nu^0_{t+1}(\ell)\frac{q^0_{\text{DM}t+1}(\ell)}{q_{\text{DM}t}(\ell)}\right](1+\kappa) - \mathbb{E}\left[\nu^0_{t+1}(\ell)\right]R_d\kappa\right)\right).$$

These equations are obtained by solving the banks' recursive problems, which we omit for brevity. They are available upon request.

[21]In this case, since there is no uncertainty between secondary and primary markets, required returns are equal to realized returns.

[22]These choices are in those states in which there are excess returns of investing in risky securities. We focus in parametrizations in which this condition always holds.

The DM households' problem is similar to that in the baseline model with the addition that households can also choose intraperiod deposits (from secondary to primary markets of period t). Given that DM households are risk neutral and do not discount time between secondary and primary markets, the equilibrium interest rate for intraperiod deposits is $R^0_t = 1$. Nonfinancial DM firms face the same problem as in the baseline model, and they only make decisions in the primary-market subperiod.

The EM economy faces a problem that is similar to that in the baseline economy, with the only difference that it can choose to issue debt of different varieties $b_{\text{EM}it+1}(\ell)$ for $\ell \in [0,1]$. EM households only make choices in the primary-market subperiod. We assume that the repayment/default decision applies to all outstanding varieties.[23] The EM budget constraint under repayment is given by

$$c_{it} = y_{\text{EM}t} + z_{it} + \int \left[q^i_{\text{EM}t}(\ell)\left(b_{it+1}(\ell) - \xi b_{it}(\ell)\right) - b_{it}(\ell)\right] \mathrm{d}\ell. \tag{44}$$

It follows that, for EMs to issue positive bonds of any two varieties, their prices should be equal

$$q^i_{\text{EM}t}(\ell) = q^i_{\text{EM}t}(\ell') \tag{45}$$

for all $\ell, \ell' \in [0,1]$. Using this condition, the EM households' problem can be collapsed to the same as in the baseline model in which the EM households choose total borrowing $b_{it+1} = \int b_{it+1}(\ell)\,\mathrm{d}\ell$. The split of total debt between varieties is determined by the demand for securities, as each EM household is indifferent between issuing any of them.

Finally, we define returns and equilibrium. Returns from holding securities from secondary markets until primary markets are given by $R^{i0}_{\text{EM}t+1}(\ell) = \frac{\iota_{it+1}(1+\xi q^i_{\text{EM}t+1}(\ell))}{q^{i0}_{\text{EM}t}(\ell)}$ and $R^0_{\text{DM}t+1}(\ell) = \frac{\omega_{t+1}[\alpha A^{\alpha-1}_{\text{DM}t}+1-\delta]}{q^0_{\text{DM}t}(\ell)}$.

Definition **3.** *Given global banks' initial portfolios* $((a^i_{\text{EM}j0})_{i\in[0,\mu_{\text{EM}}]}, a_{\text{DM}j0}, d_{j,0})_{j\in[0,1]}$*, EM households' initial debt positions* $(b_{i0})_{i\in[0,\mu_{\text{EM}}]}$*, and state-contingent processes* $\{\omega_t, y_{\text{EM}t}, (z_{it}, \zeta_{it})_{i\in[0,\mu_{\text{EM}}]}\}$*, a competitive equilibrium in the global economy is a sequence of prices* $\{w_t, (q^{i0}_{\text{EM}t}, q^i_{\text{EM}t})_{i\in[0,\mu_{\text{EM}}]}, q^0_{\text{DM}t}(\ell), q_{\text{DM}t}\}^\infty_{t=0}$ *and allocations for DM households* $\{c_{\text{DM}t}, d^0_{t+1}, d_{t+1}\}^\infty_{t=0}$*, EM households* $\{((c_{it}, b_{it+1}(\ell), \iota_{it})_{\ell\in[0,1]})_{i\in[0,\mu_{\text{EM}}]}\}^\infty_{t=0}$*, nonfinancial firms* $\{h_t, k_{t+1}\}^\infty_{t=0}$*, and global banks* $\{((a^{i0}_{\text{EM}jt+1}(\ell), a^i_{\text{EM}jt+1}(\ell))_{i\in[0,\mu_{\text{EM}}]}, a^0_{\text{DM}jt+1}, a_{\text{DM}jt+1}, d^0_{jt+1}, d_{jt+1})_{j\in[0,1]}\}^\infty_{t=0}$ *such that*

i. Allocations solve agents problems at the equilibrium prices,

ii. Assets and labor markets clear.

[23]This assumption is motivated by the fact that crossdefault clauses in bonds prevent discriminatory defaults on different securities, especially when issued in the same market.

It is worth analyzing how each asset market clears. Denote as $\mathcal{J}(\ell)$ the set of banks that specialize in variety ℓ. Market clearing in the primary market implies

$$\int_{j\in\mathcal{J}(\ell)} q^i_{\mathrm{EM}t} a^i_{\mathrm{EM}jt}(\ell)\,\mathrm{d}j = q^i_{\mathrm{EM}t} b_{it+1}(\ell), \tag{46}$$

$$\int_{\ell\in[0,1]}\int_{j\in\mathcal{J}(\ell)} q_{\mathrm{DM}t} a_{\mathrm{DM}jt}\,\mathrm{d}j\,\mathrm{d}\ell = k_{t+1}. \tag{47}$$

Equation (46) refers to market clearing of variety ℓ issued by EM economy i. In this case, since EMs are indifferent in how they split their total issuance into different varieties, equilibrium quantities are determined by their demand and prices are the same for all varieties of a given economy i. Equation (47) refers to market clearing of the DM risky security. Market clearing in the secondary market of trading network ℓ implies

$$\int_{j\in\mathcal{J}(\ell)} q^{i0}_{\mathrm{EM}t} a^{i0}_{\mathrm{EM}jt}(\ell)\,\mathrm{d}j = \int_{j\in\mathcal{J}(\ell)} q^{i0}_{\mathrm{EM}t} a^{i}_{\mathrm{EM}jt-1}(\ell)\,\mathrm{d}j, \tag{48}$$

$$\int_{j\in\mathcal{J}(\ell)} q^{0}_{\mathrm{DM}t}(\ell) a^{0}_{\mathrm{DM}jt}\,\mathrm{d}j = \int_{j\in\mathcal{J}(\ell)} q^{0}_{\mathrm{DM}t}(\ell) a_{\mathrm{DM}jt-1}\,\mathrm{d}j. \tag{49}$$

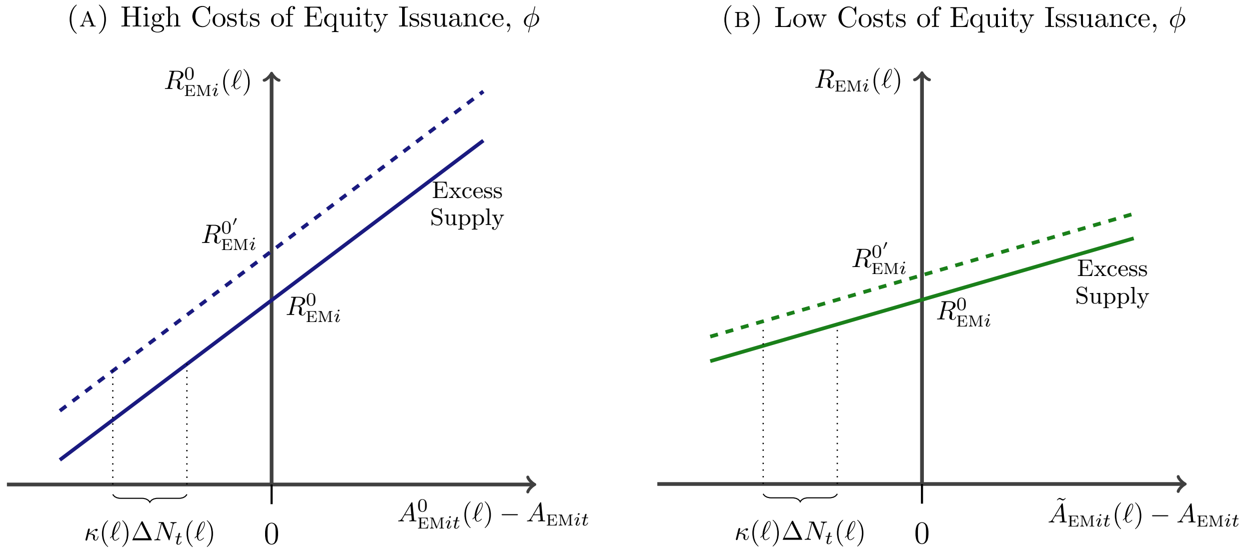
In each secondary market, the stock of outstanding securities is given by the amount of securities of that type purchased by banks in the same trading network in the previous primary market. Hence, ex-post heterogeneity across trading networks can give rise to price dispersion of securities of different varieties. Importantly, these prices can only arise in secondary markets. In primary markets, the fact that each EM household can issue any variety prevents these price differences' persistence.

B.2. *Mapping the Secondary-Markets Model to the Data*

We recreate the episode of analysis from the empirical section in the secondary-markets model. We do this by focusing on an aggregate negative shock to ω, combined with an unexpected idiosyncratic shock to the maximum amount of leverage banks can take. This shock is introduced with a mean preserving spread to the borrowing constraint parameter at the trading network level, $\kappa(\ell)$. This combination of shocks introduces ex-post heterogeneity across trading networks, and allows us to study the differential effect on securities from the same borrower held by different investors. It is motivated by the view that the global financial crisis featured an aggregate shock combined with runs on the liabilities of certain financial institutions (see, for example, Gertler and Kiyotaki, 2015; Foley-Fisher et al., 2019).[24]

[24] An alternative version of the model in which dispersion is generated by idiosyncratic shocks to the returns of DM firms delivers similar results.

FIGURE B1. Equilibrium in the Secondary Market



We now illustrate how this combination of shocks can lead to different required returns for securities of different varieties in secondary markets and how this differential effect is disciplined by the marginal cost of external finance, ϕ. 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 for additional securities, is zero. The excess supply is increasing in required returns in the secondary market since optimal equity issuance is increasing in returns as noted in (43). 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 B1.

Consider now a negative realization of $\kappa(\ell)$ in a particular trading network, that reduces the amount of deposits that banks in that trading network can roll over. 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 B1a, and increases the equilibrium required return. The net worth of banks in this trading network also falls since all their assets are now worth less. The mechanics of this shock are better understood with the following example. Consider a mass of banks in a trading network that experience a drop in κ. These banks now need to sell some of their assets to satisfy their borrowing constraint. To purchase these assets, other banks in the trading network issue new equity, but they are only willing to do so if the return from purchasing the assets is higher. Therefore, a negative shock to $\kappa(\ell)$ triggers a fire sale on risky securities.

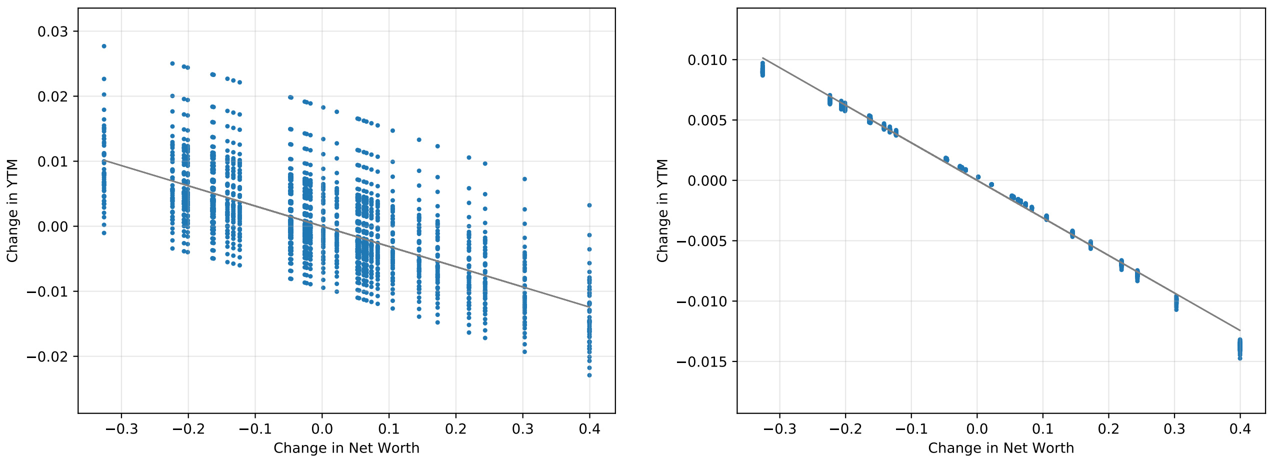
How much secondary market prices respond to shocks to $\kappa(\ell)$ depends on the banks' marginal cost of issuing equity, ϕ. Consider an economy with high costs of equity issuance (high ϕ). In this economy, the excess supply of funds is steep, since banks require a significant increase in returns to issue equity to finance purchases of additional risky securities. As shown in Figure B1a, a shock to $\kappa(\ell)$ will be associated with 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 ϕ. In this economy, it is less costly for banks to recapitalize; therefore, prices and returns need to respond less to the same magnitude shock to $\kappa(\ell)$ to induce equity issuance and restore equilibrium. This can be seen in Figure B1b. This analysis suggests that, as in the baseline model, the degree of price drops in response to shocks to banks' net worth is informative of the degree of financial frictions banks face. The difference is that, in this model, this differential response is also manifested at the cross-section of bond varieties in secondary markets.

We then use this model to quantitatively reproduce the empirical analysis from Section 3 in model-simulated data. The objective is to show that the same parametrization of the baseline model generates a cross-sectional elasticity that is consistent with that estimated from the data. We parametrize this model using the same parameter values as in the baseline model (see Tables 3 and 4).[25] We then feed into the model a shock to ω such that banks' aggregate net worth falls by 12%, as it did in the window around the Lehman episode (see Table 1), together with idiosyncratic shocks to the borrowing constraint. To generate dispersion in the borrowing constraints across trading networks, we simulate various $\kappa(\ell)$ from a lognormal distribution with mean 4.5 (which is the κ in the baseline model), and standard deviation $\sigma_\kappa^2 = 0.33$. We calibrate σ_κ^2 so that the cross-sectional standard deviation of the fall in net worth across trading networks is the same as the cross-sectional standard deviation of the fall in net worth per bond in the empirical section, 17%. We then compute yields to maturity (obtained from secondary-market prices) of 30 different varieties of bonds from 60 different countries in the model, maintaining the share of average bonds per country found in the data. We also compute the change in net worth in each of the 30 trading networks that trade different varieties. Figure B2a shows the raw simulated data, with the demeaned change in log net worth at the variety/trading-network level on the horizontal axis, and the demeaned change in yields on the vertical axis. The negative

[25]We include one extra parameter in this model not featured in the baseline model, $\overline{n}^0$, which we calibrate so that the within-period average return from holding risky debt from the secondary market to the primary market is one.

Figure B2. Change in Yield to Maturity and Holders' Net Worth: Model-Simulated Data

(A) Without Country Fixed Effects (B) With Country Fixed Effects



Notes: Panel (A) shows the model-simulated data on bond-yield and net-worth changes. The horizontal axis includes the demeaned change in net worth for each variety (and trading network). The vertical axis shows the demeaned change in bond yields of different countries and varieties. Panel (B) shows the same graph as in Panel (A), but now the change in yields is reduced to a residual from country-average change in yields.

slope of the line of best fit indicates a negative relationship between the change in bond yield and the change in bond holders' net worth. This relationship does not fully explain the simulated data, as there is dispersion in changes in yields of a given variety, due to heterogeneity in default risk that comes from different borrowers. Once this borrower heterogeneity is filtered out with fixed effects, the change in net worth accounts for most of the residual change in yields almost linearly (see Figure B2b).

We then estimate the regression on model-simulated data:

$$\Delta ytm_{i\ell} = \alpha_i + \beta \Delta N_\ell + \epsilon_{i\ell}, \tag{50}$$

where $\Delta ytm_{i\ell}$ is the one-period change in the yield to maturity of a bond of variety ℓ, issued by economy i, where the period corresponds to the joint shock to ω and $\kappa(\ell)$; α_i is a borrower fixed effect; ΔN_ℓ is the change in log aggregate net worth of the banks that trade variety ℓ. This regression is the equivalent to the empirical regression (18) without controls, as these are not featured in the model. Table B1 shows the estimated value of β in the regression with model-simulated data, and compares it with the average empirical estimate. The estimated

Table B1. Elasticity in the Secondary Market: Data and Model

	Model	Data
Cross-sectional elasticity of YTM - NW	-0.031	-0.058

Notes: The first column shows the point estimate of β from specification (50) on model-simulated data with OLS esimtation. The second column reports the average point estimate from specification (18), estimated over horizons that range from 3 t0 60 days after the Lehman-bankruptcy episode.

cross-sectional elasticity in the model is -0.031, similar to the average elasticity of -0.058 estimated in the empirical analysis.

This results confirms that, by calibrating the aggregate elasticity in the model, this model is sill able to replicate the cross-sectional elasticity. The reason is that both elasticities are identified by banks' marginal cost of raising external finance.

Appendix C. Empirical Analysis

C.1. *Data Description and Analysis*

Our sample of countries includes those countries that, at some point, were part of the EMBI, and that had a credit rating (from Standard & Poor's) below A in 2008.q2. The objective is to capture emerging economies with risky debt. For each country in the sample, we collect information on all bonds issued in foreign markets before 2008 and maturing after 2010. The average country issued 15 bonds. For each bond, we observe a borrower identifier, the country and sector of the borrower, the amount issued and outstanding, the coupon structure, and the maturity. We complement this data with daily bond-price data provided by Bloomberg based on information gathered from trading desks.

Table C1 reports descriptive statistics of our sample of bonds for those countries with the largest number of bonds. Across countries, there is significant yield-to-maturity heterogeneity, and moderate heterogeneity in maturities and bid–ask spreads.

Table C2 reports similar statistics for bonds by sector. Approximately half of the bonds of our sample are sovereign bonds and half are corporate bonds. Corporate bonds issued by financial firms account for half of the sample. Across sectors, there is some yield-to-maturity, maturity, and bid–ask-spread heterogeneity.

TABLE C1. Descriptive Statistics by Country

Country	N Bonds	YTM	Maturity	Bid-Ask Spread
Argentina	33	12.8%	457	0.66%
Brazil	55	8.5%	598	0.43%
Colombia	19	7.1%	324	0.40%
Costa Rica	5	5.9%	201	0.44%
Greece	13	6.3%	229	0.18%
Croatia	7	6.1%	146	0.43%
Indonesia	15	7.0%	455	0.30%
India	24	6.4%	310	0.45%
Jamaica	6	8.3%	425	0.69%
Kazakhstan	34	11.9%	225	0.52%
Lebanon	7	8.0%	208	0.42%
Mexico	59	7.2%	343	0.38%
Panama	13	6.5%	472	0.49%
Peru	9	7.1%	424	0.39%
Philippines	21	6.4%	369	0.36%
Pakistan	5	12.6%	367	0.63%
Poland	15	4.6%	212	0.22%
Russia	6	6.3%	390	0.18%
Thailand	11	8.6%	219	0.38%
Turkey	19	6.4%	334	0.33%
Ukraine	11	9.6%	211	0.31%
Uruguay	10	6.3%	544	0.55%
Venezuela	15	11.7%	398	0.47%
South Africa	16	8.4%	232	0.53%
Average	18	7.9%	337	0.58%

Notes: This table shows descriptive statistics by country of the EM bonds included in the empirical analysis of Section 3, for those countries with five or more bonds. N Bonds refers to the number of bonds available per country. YTM refers to the bond's average yield to maturity in percent. Maturity refers to the average residual maturity in days. Bid–ask spread is expressed in percent. All averages are computed using their values before the Lehman episode (10 days before September 15, 2008).

Table C3 shows the average yield to maturity and its cross-sectional standard deviation, two months before and after Lehman's bankruptcy episode. Average yields increased by two percentage points on average, and its cross-sectional standard deviation also increased by two percentage points. Similar patterns hold if we focus exclusively on sovereign bonds.

Table C2. Shares by Sector of Bonds Included in the Empirical Analysis

Sector	Share	YTM	Maturity	Bid–Ask Spread
Government	53.9%	7.2%	385	0.42%
Industrial	3.4%	13.6%	201	0.83%
Financial	21.0%	9.8%	332	0.52%
Utilities	3.6%	9.2%	238	0.56%
Communications	6.0%	9.2%	345	0.51%
Energy	4.7%	7.6%	290	0.42%
Other	7.4%	8.7%	495	0.68%
Average	15.4%	9.4%	298	0.54%

Notes: This table reports descriptive statistics of bonds by sectors included in the empirical analysis of Section 3. The first column shows the average share of bonds. Other groups consumer (68%), basic materials (35%), diversified (7%), and technology (0.5%). YTM refers to the average yield to maturity in percent. Maturity refers to the average residual maturity in days. Bid–ask spread is expressed in percent. All average variables are computed using their values before the Lehman episode (10 days before September 15 2008). Source of data and sector definitions: Bloomberg.

We then assess the extent to which bonds' yields to maturity can be explained by bond and borrower characteristics. To do this, we estimate the following empirical model

$$y_{it} = \alpha_{kst} + \alpha_{ct} + \gamma_t' Z_{it} + \varepsilon_{it}, \tag{51}$$

where y_{it} denotes the log gross yield to maturity of bond i in period t, α_{kst} denotes a country of issuance (k) by sector (s) by time fixed effect, and Z_{it} is a vector of bond-level controls that includes residual maturity, bid–ask spread, amount outstanding, and initial yield.[26] The last four rows of Table C3 show the average R^2 of running daily regressions on different sets of controls. The sole inclusion of country–sector and currency fixed effects already accounts for around 75% of the observed yield variation. If we include the full set of controls, the empirical model can account for 99% of the variation from the pre-Lehman period.

Table C3 also shows that the explanatory power of the empirical model is significantly undermined post-Lehman relative to pre-Lehman. The largest R^2 is 99% pre-Lehman compared to 85% post-Lehman. Similar patterns hold if we focus exclusively on sovereign bonds. This fact

[26]Initial yield corresponds to the yield of 60 days before the Lehman episode, for those regressions with pre-Lehman data, and to the yield at the Lehman episode for those regressions with post-Lehman data.

Table C3. Bond Yields to Maturity Before and After the Lehman Episode

	All Bonds		Only Sovereign	
	Pre-Lehman	Post-Lehman	Pre-Lehman	Post-Lehman
Average	6.72%	8.75%	6.18%	8.04%
Cross-Sec. Std. Deviation	10.90%	12.43%	2.76%	4.80%
R^2 from Yield Regressions				
(1): Country–Sector FE	67.3%	71.2%	65.9%	72.7%
(2): (1) + Currency FE	78.1%	75.8%	77.9%	75.8%
(3): (2) + Additional Controls	79.1%	75.6%	80.0%	76.8%
(4): (3) + Initial Yield	98.6%	85.1%	96.4%	88.8%

Notes: This table reports summary statistics for the pre-Lehman and post-Lehman periods (two months before and after Lehman's bankruptcy episode, respectively). The first two columns use data from all bonds, and the last two columns uses data from sovereign bonds. The first two rows show the average and cross-sectional standard deviations. The remaining rows report the average R^2 of running daily regressions from specification (51), for the pre- and post-Lehman periods. Different rows expand the set of controls used. The first row uses country–sector fixed effects; the second also includes currency fixed effects; the third also includes maturity, bid–ask spreads and amount outstanding as additional controls; the last row also includes initial yields.

suggests a significant increase in yield dispersion after Lehman that cannot be explained from bonds' observable characteristics. This motivates us to focus on this episode, which displays considerable bond price deviations that may be related to other factors. We analyze how this unexplained variation is related to bond holders' differential performance during this episode.

The most novel part of our data is the data on holdings from financial institutions for each bond in the sample. These data are provided by Bloomberg. We obtained data on the holdings by financial institution as of the end of 2008.q2. The holdings are reported voluntarily by major financial institutions. These institutions include global and national banks, asset-management firms (mutual funds, hedge funds, and financial advisors), pension funds, insurance companies, holding companies and other financial institutions. The total reported holdings of all financial institutions account for 25%, on average, of the total amount outstanding of a bond.[27]

Among the reporting financial institutions, we focus on the 67 publicly traded institutions, for whom we are able to measure the change in their stock price around the Lehman episode

[27]This is consistent with the fact that a sizable fraction of external debt is held by central banks and other official institutions (see Arslanalp and Tsuda, 2014).

Table C4. Financial Institutions Included in the Empirical Analysis

Aegon NV	GE Capital	Northern Trust
Allianz SE	Genworth Financial	PNC
Allstate	Goldman Sachs	Principal Financial Group
American International Group	HSBC	Prudential Financial
Ameriprise Financial	Hartford	Raiffeisen Bank International AG
Ares Management	Huntington Bancshares	Regions
BNP Paribas	Intesa Sanpaolo	Royal Bank of Canada
BNYM	Invesco	SEI Investments Co
Banca Mediolanum	JPMorgan	Schroders
Banco Bilbao Vizcaya Argentaria	Janus Henderson Group	Societe Generale
Banco Santander	KBC Group NV	Standard Life Aberdeen
Bank of America	Legg Mason	State Street
Barclays Bank	Loomis Sayles	Sumitomo Mitsui Financial Group.
BlackRock	M&T Bank	Sun Life Financial
CIBC	Merrill Lynch	T Rowe Price Group
Citigroup	MetLife	TD Bank
Commonwealth Bank of Australia	Mitsubishi UFJ	U.S. Bancorp
Credit Suisse	Morgan Stanley	UBS
Daiwa Securities Group	NN Group NV	UniCredit
Deutsche Bank	Natixis	Virtus Investment Partners
Fidelity National Financial	Nikko Asset Management Co	Wells Fargo
Franklin Resources	Nomura Holdings	
GAM Holding AG	Nordea Bank Abp	

(Table C4). These institutions constitute our sample of financial institutions. Major global banks (e.g., JPMorgan, Deutsche Bank, Goldman Sachs, BNP Paribas, Citigroup) and major asset managers and insurance companies (e.g. AIG, BlackRock, Allianz) are included in the sample. The institutions in our sample hold 46%, on average, of total reported bond holdings in our sample (see Table 1). Table C5 reports descriptive statistics for the top 20 financial institutions in terms of numbers of EM bonds held. These institutions hold more than 150 bonds on average from a wide set of countries. Importantly, these financial institutions experienced differential capital shocks in the narrow window around Lehman's bankruptcy (see the last column of Table C5). To give an illustrative example, while JPMorgan did not experience a stock price drop, AIG experienced a drop in its stock price of 88% (-2.12 in log terms). This heterogeneity, which was due to the differential impact of their business activities in developed markets, is the focus of our empirical analysis.

Table C5. Descriptive Statistics by Financial Institution

Financial Institution	N Bonds	N Countries	Avg Share	Δe_i
Allianz SE	340	34	31.2%	-0.12
JPMorgan	258	26	10.3%	0.02
Aegon NV	245	25	11.8%	-0.23
Deutsche Bank	225	32	17.9%	-0.07
UBS	219	31	27.8%	-0.33
BNP Paribas	219	33	9.8%	-0.03
BNYM	214	31	9.9%	-0.14
Hartford	210	27	13.7%	-0.08
American International Group	182	25	9.2%	-2.12
SEI Investments Co	165	28	13.4%	-0.17
NN Group NV	165	27	35.3%	-0.03
Goldman Sachs	155	26	13.4%	-0.41
Raiffeisen Bank International AG	152	34	12.4%	-0.23
Wells Fargo	142	23	3.3%	0.17
GAM Holding AG	139	31	29.9%	-0.03
HSBC	136	28	11.0%	-0.02
Credit Suisse	128	23	32.8%	-0.03
Mitsubishi UFJ	94	21	19.4%	0.05
Nordea Bank Abp	92	25	3.5%	-0.04
Morgan Stanley	83	23	22.8%	-0.61
Average	178	28	16.9%	-0.22

Notes: This table shows descriptive statistics of the 20 financial institutions included in the empirical analysis of Section 3 holding the 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 issuing these bonds. Avg share denotes a financial institution's average share of reported holdings of a particular bond before the Lehman episode (2008.q2). Δn_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 to three days after).

C.2. *Empirical Results: Robustness and Further Analysis*

This section presents additional empirical work that strengthens the validity of the identification strategy and argues that the main empirical results are robust to alternative specifications.

We first argue that our empirical results are not driven by selection. One concern related to the empirical results from model (18) is that financial institutions more severely affected by the Lehman episode could have a portfolio tilted towards more risky bonds, which experienced

Table C6. EM Bonds' Characteristics by Holders' Change in Net Worth

	No Fixed Effects		Country by Sector FE	
	$\Delta e_i < \Delta\bar{e}_i$	$\Delta e_i > \Delta\bar{e}_i$	$\Delta e_i < \Delta\bar{e}_i$	$\Delta e_i > \Delta\bar{e}_i$
Residual Maturity	361	365	-28.9	18.97
	[265]	[286]	[237.7]	[214.5]
Bid–Ask Spread	0.43%	0.51%	-0.02%	0.02%
	[0.02%]	[0.01%]	[0.01%]	[0.02%]
Yield (Pre-Lehman)	7.9%	8.4%	-0.18%	0.12%
	[0.25%]	[0.25%]	[0.16%]	[0.14%]
Amount Issued	20.56	20.25	-0.00	0.000
	[0.079]	[0.080]	[0.063]	[0.057]

Notes: The first two columns of this table show the mean maturity, bid–ask spread, amount issued, and yield to maturity of bonds whose holders' change in net worth was less than the mean ($\Delta e_i < \Delta\bar{e}_i$) and more than the mean ($\Delta e_i > \Delta\bar{e}_i$). The last two columns show the averages for the same variables after subtracting country-sector means. Residual maturity is expressed in days, bid–ask spreads in percent, yields in annual terms and amount issued in log of U.S. dollars. Standard errors are in brackets.

larger price drops during the crisis. We argue that this is not the case. In particular, we observe no sorting of financial institutions into bonds with different observable characteristics within each country sector. Table C6 reports average observable bond characteristics for those bonds whose holders' net worth fell by more, and less, than average. The first two columns report the unconditional averages for these two groups, and the last two columns report the averages after reducing variables to residuals from country–sector means. The average residual maturity, bid–ask spread, pre-Lehman yield to maturity, and amount outstanding of those bonds held by more- and less-distressed financial institutions are not statistically different from each other. These differences become smaller once we filter out country–sector differences.

We strengthen the point of no sorting among these covariates by estimating a regression for each bond covariate on the change holders' net worth. We then analyze the statistical significance of the coefficient associated with the change in the bond holders' net worth, the independent variable, a more formal way to identify a monotonic relationship between these variables. Table C7 shows the estimated coefficients of separately regressing residual maturity, bid–ask spread, initial yields, and amount outstanding on the change in bond holders' net

Table C7. Regressions of Bond Covariates on Change in Holders' Net Worth

	With FE	Without FE
Residual Maturity	0.155	0.670
	[0.677]	[0.526]
BA Spread	0.001	0.002
	[0.002]	[0.002]
YTM	0.015	0.007
	[0.034]	[0.034]
Amount Outstanding	1.755	3.139
	[2.000]	[2.824]

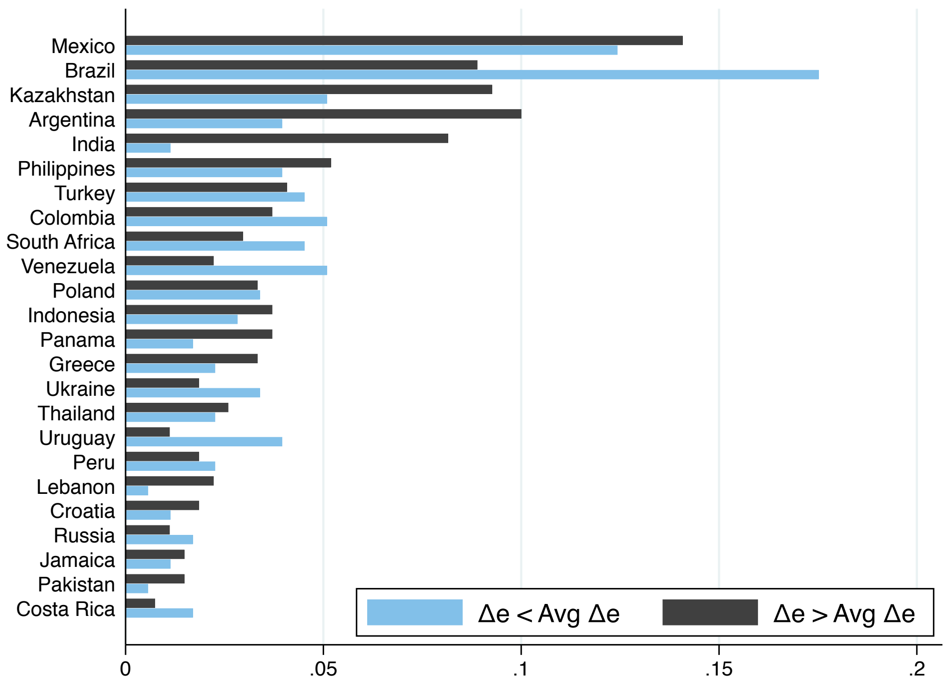
Notes: This table reports the estimated coefficients of regressing different covariates on the change in bond holders' net worth. Each row corresponds to a different regression in which the dependent variable is indicated in the first column. The first (second) column corresponds to a regression specification without (with) country–sector fixed effects. Residual maturity, and amount outstanding are expressed in logs for the regression. Standard errors of the estimated parameters are in brackets.

worth, with and without country–sector fixed effects. No estimated coefficients are statistically different from zero, confirming the absence of sorting along these dimensions.

We then analyze whether we observe sorting of financial institutions across countries and sectors. Following a similar approach as before, we separate bonds into those whose holders' net worth decreased by more and less than the average, and analyze the distribution of those bonds across countries and sectors. Figure C1 shows some degree of sorting of financial institutions into different countries. Financial institutions that were more severely hit during the Lehman episode held more bonds from Brazil, while those institutions that were less hit had more bonds from Mexico, Argentina, and India. We also perform a similar analysis by sector. Table C8 shows that there is some degree of sorting of financial institutions into different sectors. Financial institutions more severely hit during the Lehman episode held more sovereign bonds than those institutions that were less hit.

In summary, our analysis shows no evidence of sorting among financial institutions into bonds with different maturities and liquidities, two dimensions that could potentially affect bond-price dynamics during the Lehman episode. In contrast, the data point towards financial institutions sorting into bonds from different countries and sectors. This sorting could be due to financial institutions acquiring specialized knowledge on certain country and sectors and, therefore, investing more heavily in those countries and sectors. The presence of sorting along

Figure C1. Sorting of Financial Institutions into Countries



Notes: This figure shows the share of bonds by country among the set of bonds whose holders' net worth changed by less than average ($\Delta e < \text{Avg}\Delta e$), and among the set of bonds whose holders' net worth changed by less than average ($\Delta e > \text{Avg}\Delta e$).

Table C8. Sorting of Financial Institutions into Sectors

Sector	All bonds	$\Delta e_i < \Delta \bar{e}_i$	$\Delta e_i > \Delta \bar{e}_i$
Government	53.9%	66.7%	45.6%
Industrial	3.4%	4.0%	3.0%
Financial	21.0%	11.3%	27.4%
Utilities	3.6%	4.0%	3.3%
Communications	6.0%	4.5%	7.0%
Energy	4.7%	4.5%	4.8%
Other	7.4%	5.1%	8.9%

Notes: This table reports the share of bonds by sectors. The first column shows the share among all bonds included in the analysis. The second (third) column shows the share among those bonds whose holders' net worth changed by less (more) than average ($\Delta e_i < \Delta \bar{e}_i$ and $\Delta e_i > \Delta \bar{e}_i$, respectively).

TABLE C9. Effect of Global Financial Intermediaries' Net Worth on EM Yields: Alternative Windows

	Baseline	Tighter Window	Wider Window
	(1)	(2)	(3)
Impact Effect	-0.013***	-0.017***	-0.006
	(0.004)	(0.006)	(0.008)
Peak Effect	-0.135**	-0.176***	-0.143**
	(0.053)	(0.066)	(0.057)
N Observations	402	402	402

Notes: This table shows the estimated elasticity of bonds' yields to maturity, β_h, to changes in the holder's net worth at two different horizons h, from estimating regression 18. The peak effect corresponds to the most-negative estimated elasticity over all horizons up to two months. Column (1) refers to the baseline estimation. Columns (2) and (3) refer to the same specification in which the change in the stock price of bond holders is computed over a window of five and 20 days around the Lehman's bankruptcy episode, respectively. Robust standard errors are in parentheses, and *, **, and *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

these observable dimensions does not confound our empirical estimates since we can control for the country–sector dimention in the best possible way with the introduction of country–sector–time fixed effects.

We now present additional empirical analysis that shows that the main empirical results are robust to alternative specifications. First, we estimate the same baseline specification (18) while varying the length of the window over which we compute the change in bond holders' stock price. We consider a tighter window of five days around Lehman's bankruptcy, and a wider window of 30 days, compared to the baseline window of 13 days. Results, shown in Table C9, remain roughly unchanged, with similar point estimates for the on-impact and peak effects.

We then estimate the same baseline specification in different subsamples. Results are reported in Table C10. We first estimate the main regression using bonds denominated in U.S. dollars. This specification isolates our model from differential currency risk. Results, reported in Column (2), are robust to considering this alternative sample. We then estimate the baseline specification in which we only consider global banks when computing the change in bond holders' stock price. This is motivated by the fact that other financial institutions like asset managers and insurance companies may be less subject to financial frictions. Hence, one

TABLE C10. Effect of Global Financial Intermediaries' Net Worth on EM Yields: Robustness Analysis

	Baseline	Only Dollar	Only Banks	Exc. Mkt. Makers
	(1)	(2)	(3)	(4)
Impact Effect	-0.013***	-0.012***	-0.024	-0.013**
	(0.004)	(0.004)	(0.015)	(0.006)
Peak Effect	-0.135**	-0.134**	-0.235***	-0.143***
	(0.053)	(0.052)	(0.090)	(0.049)
N Observations	402	305	356	397

Notes: This table shows the estimated elasticity of bonds' yields to maturity, β_h, to changes in the holders' net worth at two different horizons h, based on regression 18. The on-impact effect corresponds to the estimated elasticity when the change in yields is computed from 10 days before to three days after Lehman's bankruptcy. The peak effect corresponds to the most negative estimated elasticity over all horizons before two months. Column (1) refers to the baseline estimation. Columns (2) and (3) refer to the same specification in which the change in bond holders' stock price is computed over a window of five and 20 days around the Lehman's bankruptcy episode, respectively. Robust standard errors are in parentheses, and *, **, and *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

should expect results to remain significant if we narrow attention to just global banks as holders. Results, reported in Column (3), are robust to narrowing attention to global banks. In fact, the estimated peak elasticity in this case is larger (in absolute value) than in the baseline specification. Finally, we also estimate the baseline specification in which we exclude market makers when computing the change in the stock price of bond holders. This robustness analysis is aimed at isolating a potentially confounding mechanism that may operate through the undermined ability of market makers to provide liquidity during Lehman's bankruptcy episode. During this episode the market-making activity of some institutions could have been impaired by shocks to the value of their firm. The last column of Table C10 reports the results on this alternative sample of financial institutions, which feature similar point estimates as in the baseline specification.

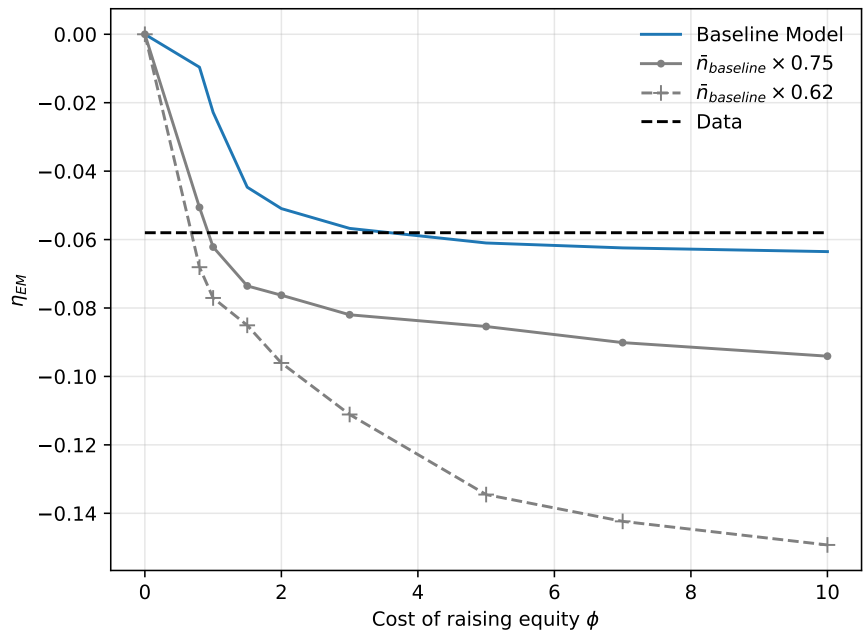
Appendix D. Additional Figures and Tables

Table D1. Major Financial Institutions' Balance Sheets

Financial Institution	Ratio of Sovereign Non-U.S. Debt to Assets	Ratio of Sovereign Non-U.S. Debt to Risky Assets	Ratio of Risky Assets to Equity
Aegon	0.044	0.32	1.9
Allianz	0.072	0.17	7.8
American International Group	0.008	0.28	0.3
Ameriprise	0.001	0.02	1.1
Banco Santander	0.054	0.41	2.3
Bank of America	0.022	0.06	3.8
Barclays	0.052	0.43	5.5
CIBC	0.005	0.01	9.9
Citigroup	0.058	0.14	6.7
Deutche Bank	0.005	0.04	4.1
Goldman Sachs	0.021	0.4	1.2
Hartford	0.002	0.21	0.3
HSBC	0.08	0.13	9.8
Intesa	0.053	0.67	1.2
JPMorgan	0.048	0.15	3.8
Merrill Lynch	0.026	0.39	1.4
MetLife	0.024	0.11	3.3
Mitsubishi	0.021	0.08	4.8
Morgan Stanley	0.025	0.51	1.6
PNC	0.001	0.003	3
Principal Financial Group	0.006	0.23	0.5
UBS	0.03	0.21	6.2
Wells Fargo	0.014	0.03	4.9
Average	0.048	0.139	5.5

Notes: This table shows selected items from the balance sheets of the main global financial institutions included in the empirical analysis of Section 3 (listed in Table C4), with available balance-sheet data. The first column shows the ratio of claims on non-U.S. sovereigns to total assets. The second column shows the ratio of claims on non-U.S. sovereigns over risky assets. The third column shows the ratio of risky assets to equity for each financial institution. The last row represents the weighted average across the financial institutions in the sample, using their net worth as weights. For most financial institutions included in this sample, balance-sheet data are publicly available at AnnualReports.com.

FIGURE D1. The Role of Financial Frictions in the Elasticity of EM-Bond Yields to Global Banks' Net Worth



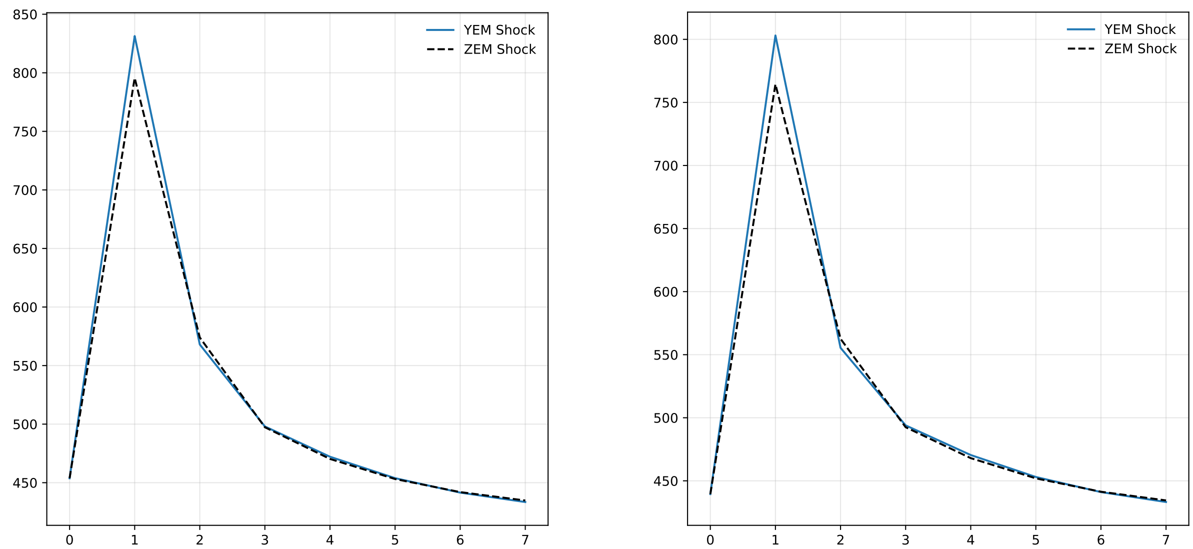
Notes: This plot shows the estimated elasticity of change in EM bonds' yields to maturity to changes in the log market value of global banks' net worth for different values for the cost of equity issuance, ϕ. The solid blue line represents the elasticity under the baseline calibration, with only ϕ being changed. The solid gray line is the case where we parametrize the economy with a lower $\bar{n}$ of 0.75 times the baseline parametrization, and the dashed gray line represents the economy with an even lower $\bar{n}$ of 0.62 times the baseline. Neither case involved further changes in parameters aside from $\bar{n}$ and ϕ. The flat black dashed line is the elasticity estimated in the data, in Section 3.

TABLE D2. Major U.S. Banks Exposure: 1980s

	1982	1984	1986
EM Debt -to-Capital			
All Banks	186.5%	156.6%	94.8%
Top 9	287.7%	246.3%	153.9%

Notes: This table shows selected items of U.S. commercial banks' balance sheets from the 1980s. EM debt-to-capital refers to the ratio of banks' claims on developing countries to banks' primary capital. Top nine banks refers to the largest nine U.S. banks during the 1980s. Source: Sachs (1989).

FIGURE D2. Amplification with Low Exposure



(A) Ergodic Dispersion of EM Debt (B) High Dispersion of EM Debt

Notes: These figures show the dynamics of spreads following a two-s.d. shock to the systemic and idiosyncratic endowment, when global banks' exposure to EMs is 10% (baseline calibration). The left panel shows the case where the initial distribution is the ergodic distribution, while the right panel starts with a distribution with twice its dispersion. Spreads are expressed in basis points. The blue solid line shows the reaction of spreads to the systemic endowment and the black dashed line shows the reaction to an idiosyncratic endowment shock.

APPENDIX E. APPENDIX QUANTITATIVE ANALYSIS

E.1. *Solution Method*

As discussed in Appendix A.1, our model agents' heterogeneity and aggregate uncertainty imply that the distribution of assets in the world economy, Δ, 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 EM's 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.[28] 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, $\hat{A}_{\text{DM}}(\mathbf{s})$, which governs DM firms' marginal product of capital. In equilibrium, perceived policies, in turn, must coincide with actual policies. To avoid inaccuracies originating in this perceived policy function, we instead choose an auxiliary aggregate variable, $\hat{A}_{\text{DM}}$, describing aggregate investment in DM firms at the end of the period as a state variable in agents' individual problems. Using $\hat{A}_{\text{DM}}$ 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. We express global banks recursive problem as

$$\nu(s_x) = (1-\sigma) + \sigma\left(\frac{1}{4\phi}\left(\beta_{DM}\mathbb{E}\left[\nu(s_x')R_{DM}(s_x', s_x)\right] - 1\right)^2 + \beta_{DM}\left(\mathbb{E}\left[\nu(s_x')R_{DM}(s_x', s_x)\right](1+\kappa) - \mathbb{E}\left[\nu(s_x')\right]R_d\kappa\right)\right)$$

$$\hat{A}'_{\text{DM}} = \mathcal{F}_A(s_x, \hat{A}_{\text{DM}}, m) \tag{52}$$

$$m' = \mathcal{F}_m(s_x, \hat{A}_{\text{DM}}, m), \tag{53}$$

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

Individual EMs' repayment decision under our approximate solution is characterized by

$$V(b, z, s_x, \hat{A}_{\text{DM}}, m) = \max_{\iota} \iota V^{\text{r}}(b, z, s_x, \hat{A}_{\text{DM}}, m) + (1-\iota)V^{\text{d}}(z, s_x, \hat{A}_{\text{DM}}, m), \tag{54}$$

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

$$V^{\text{r}}(b, z, s_x, \hat{A}_{\text{DM}}, m) = \max_{b'} u(c) + \beta\mathbb{E}\left[V(b', z', s_x', \hat{A}'_{\text{DM}}, m')\right], \tag{55}$$

$$\text{s.t. } c = y_{\text{EM}} + z - b + q(b', z, s_x, \hat{A}_{\text{DM}}, m)(b' - \xi b), (52), (53),$$

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

[28]The relevance of the degree of aggregate uncertainty in our model makes us depart from algorithms that involve 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.

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

$$V^{\mathrm{d}}(z, s_x, \hat{A}_{\mathrm{DM}}, m) = u(c) + \beta \mathbb{E}\Big[\phi V^{\mathrm{r}}(0, z' s'_x, \hat{A}'_{\mathrm{DM}}, m') + (1-\phi) V^{\mathrm{d}}(z', s'_x, \hat{A}'_{\mathrm{DM}}, m')\Big], \tag{56}$$
$$\text{s.t. } c = \mathcal{H}(y_{\mathrm{EM}} + z), (52), (53).$$

For the forecasting rules, our benchmark algorithm follows Krusell and Smith (1998) in parametrizing an assumed functional form for the rule and using an iterative procedure with model-simulated data to estimate the parameters of the functional form. To make the procedure parsimonious, we assume a log-linear forecasting rule in the state variables and reduce the aggregate state space to $(s_x, \hat{A}_{\mathrm{DM}})$.[29] Our algorithm then proceeds as follows.

(1) Specify the initial forecasting rule, denoted $\mathcal{F}_A^j(\cdot)$ for $j = 0$.
(2) Solve individual agents' problems given the forecasting rule $\mathcal{F}_A^j(\cdot)$ 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 rule $\mathcal{F}_A^{j+1}(\cdot)$. Denoting by $\mathcal{F}^j(\tilde{s}_x)$ the sequence of forecasts under the rule $\mathcal{F}_A^j(\cdot)$ for the sequence $\tilde{s}_x$, compute the distance $\delta_{j+1} \equiv ||\tilde{\mathcal{F}}^{j+1}(\tilde{s}_x) - \tilde{\mathcal{F}}^j(\tilde{s}_x)||$.
(4) Update the forecast rule and iterate in steps (2) and (3) for $j = 1, 2, 3, \ldots$, until δ_{j+1} is sufficiently small.

We analyze the goodness of fit of the assumed forecast rule following Den Haan (2010), who suggests testing the accuracy of the forecast rule by performing a multiperiod forecast without updating the endogenous state variable. This method does not adjust for deviations from the true endogenous state, thus providing some sense of divergence in the model. Since the relevant variable for the borrower is the bond price, we simulate a series of bond prices under the true policy $\hat{A}_{\mathrm{DM}}$, and compare it with a series for bond prices under the multiperiod forecast of the policy $\hat{A}^f_{\mathrm{DM}}$. The steps are as follows.

(1) Draw a sample for the exogenous processes s_x.

[29] Borrowers only need $(s_x, \hat{A}_{\mathrm{DM}})$ to infer current required returns. Adding moments related to the joint distribution of assets could potentially improve forecastability, but we found that first moments of debt and deposits did not make significant improvements while they would be subject to the curse of dimensionality. Considering richer forecasting rules leads to convergence problems in the iterative procedure.

(2) Solve for the equilibrium prices and allocations in each period. In particular, obtain a realization for $\{\hat{A}_{\text{DM},t}\}_{t=1}^{T}$.

(3) Let $\hat{A}^{f}_{\text{DM},0} = \hat{A}_{\text{DM},0}$ and construct $\hat{A}^{f}_{\text{DM},t} = \mathcal{F}_{A}(\omega_t, \hat{A}^{f}_{\text{DM},t-1})$.

(4) Draw a series for idiosyncratic endowments, z, to simulate an individual borrower. Compute a series of bond prices $\{q_t\}_{t=1}^{T}$ using the actual realization of $\{\hat{A}^{f}_{\text{DM},t}\}_{t=1}^{T}$, and a series of bond prices $\{q^{f}_{t}\}_{t=1}^{T}$ using $\{\hat{A}^{f}_{\text{DM},t}\}_{t=1}^{T}$.

(5) Construct a series for log residuals $\{\log(q_t) - \log(q^{f}_{t})\}_{t=1}^{T}$ and its R^2.

The R^2 of the series is 97.4%. Figure E1 shows a subset of the time series for the log residuals, as well as the estimated density for the entire time series excluding default episodes. These results show that forecasts do not exhibit accumulation of errors over time. The predicted series closely follows the actual series for bond prices, suggesting the main driver for the DM policy is the ω shock. In addition, the residuals are most of the time centered around zero, although there is a mild negative skewness; 63% of the absolute values of the log residuals are less than 0.5%, 84% are less than 1%, and 98% are less than 2.5%. The negative skewness of the density stems from occasional overestimation of the DM policy, implying a nontrivial curvature for extreme realizations of the ω shock.[30]

E.2. *Data Used in Quantitative Analysis*

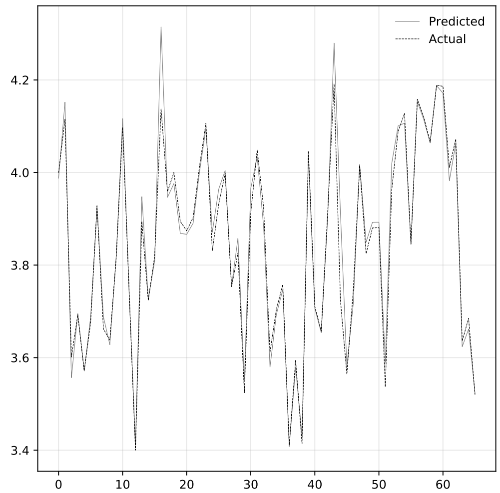
Definition of the Sample. Our sample of countries consists of emerging economies with sufficient data available to conduct the empirical analysis of Section 3, using bond-level data, and our quantitative analysis in Section 4, using aggregate data. In particular, we consider those countries that (i) 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. Twenty-five countries met the sample criteria: Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, El Salvador, Indonesia, Jamaica, Lithuania, Latvia, Mexico, Malaysia, Panama, Peru, Philippines, Pakistan, Poland, Russia, South Africa, Thailand, Turkey, Ukraine, and Venezuela.

Country Variables. For all countries in the sample, we collect daily data on sovereign spreads, and quarterly data on real GDP, real consumption, and trade balance over GDP. Sovereign spreads are a summary measure computed by JP Morgan on a synthetic basket of bonds for each 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

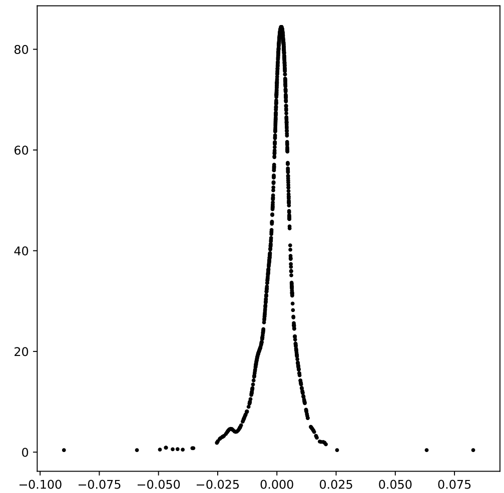
[30]As an additional exercise, we allowed for quadratic specifications on the regressors without solving again for the full model. This increases the R^2 to 98% and reduces the range of the log residuals.

Figure E1. Fundamental Accuracy Plot

(a) Actual versus Predicted



(b) Density of Log Residuals



Notes: The left panel shows a subset of the time series of the actual and forecasted versions of the bond price for a simulated individual economy. The right panel shows the estimated density of the log residuals for the entire sample. On the x-axis, we have the value for the log residual and on the y-axis the density value.

Datastream. Data on real GDP, real consumption, and trade balance ratio was obtained from national sources and the IMF. The sample period is from 1994 to 2014, but data on particular countries may have different starting points and ending points, depending on availability.

E.3. *Additional Quantitative Results*

E.3.1. *Measured Endowment Processes*

In the baseline calibration we restricted the systemic and idiosyncratic components of output to have the same stochastic process (governed by ρ_{EM} and σ_{EM}), in order to study the differential effects of these shocks that arise due to endogenous amplification, rather than due to having different stochastic processes. In this subsection we recalibrate the model using a decomposition of the systemic and idiosyncratic components of endowment estimated in the data. In particular, we measure the systemic EM endowment the cross-sectional average of the HP cycle of GDP for each of the countries in the sample. For each country, we measure its idiosyncratic component as the residual between the country's observed HP cycle of output and the constructed systemic component. We assume that both are first-order autoregressive. Table E1 shows the estimated autocorrelation coefficient and the standard deviation of the innovation. The systemic component of output is less persistent and less volatile than the idiosyncratic

Table E1. Estimated Endowment Processes

	Endowment	
	Systemic	Idiosyncratic
Autocorrelation	0.70	0.82
Shock Volatility	0.016	0.025

component. Given these new processes, we recalibrate the model to match the targets of the baseline model.[31]

The quantitative results from our baseline calibration are robust this recalibration of the model, using systemic and idiosyncratic endowment processes measured in the data. Table E2 conducts the unconditional decomposition of borrowing costs in EMs into their default- and risk-premium components. Results are similar than in our baseline calibration (Table 9), and show that 26% of the average spreads and 48% of the fluctuations in spreads can be attributed to the risk-premium component. Again, these figures are aligned with independent empirical estimates of the role of global factors for EM-bond spreads from the international-finance literature, and suggest that global banks play a key role driving these global factors. Table E2 shows the role of global banks during systemic debt crises, analyzing the bond spreads and consumption dynamics predicted by the model in response to only a drop in ω and in response to only a drop in y_{EM}, of the magnitude analyzed in the 2007–2009 episode. As in our baseline calibration, a large share of the increase in borrowing costs and consumption adjustment during the crisis can be explained by DM shocks, transmitted through global banks.

E.3.2. *Special Case:* $\kappa = 0$

Table E4 shows the relevance of global financial intermediaries during systemic debt crises in an alternative calibration of the model with $\kappa = 0$. This alternative calibration is aimed at capturing a framework in which financial intermediaries are asset managers with zero leverage. In this exercise, we recalibrate the model to match the same set of targets as in the baseline calibration. Table E4 shows that in this alternative calibration, 60% of the increase in borrowing costs and 20% of the consumption adjustment in EMs during 2007-2009 can be explained

[31] In this alternative calibration, we obtain parameter values and targeted and untargeted moments close to those of our baseline calibration. The full set of parameter values and moments of this alternative calibration are available upon request.

Table E2. Unconditional Decomposition of EM-Bond Spreads: Calibration with Measured Endowment Processes

	Average	Std Dev
Data	410	173
Model	426	185
Default Premium	317	164
Risk Premium	109	89

Notes: This table shows a decomposition of EM-bond spreads predicted by the model into their default- and risk-premium components. Figures correspond to the alternative calibration of the model using systemic and idiosyncratic endowment processes measured in the data (see Section E.3.1). We define the default-premium component of spreads as the bond spreads that would be observed, given EMs' equilibrium sequence repayment and borrowing policies, if debt were priced by a risk-neutral lender. To compute the default-premium component of spreads, we compute a sequence of risk-neutral prices, $\tilde{q}^i_{\text{EM}t} = \mathbb{E}_t\left[\beta_{\text{DM}}\iota_{it+1}\left(1+\xi\tilde{q}^i_{\text{EM}t+1}\right)\right]$, where $\{\iota_{it}\}_{t=0}^{\infty}$ denotes the sequence of state-contingent repayment policies from our baseline economy. We then compute EM yields to maturity based on risk-neutral prices $\{\tilde{q}^i_{\text{EM}t}\}_{t=0}^{\infty}$. We define the risk premium as the difference between the spreads predicted by the model and the default-premium component. The first column shows the unconditional average of each variable and the second column the unconditional volatility.

by DM shocks, transmitted through global financial intermediaries. These results are smaller than those of our baseline calibration in Table (in which two thirds of the increase in borrowing costs and a third of the consumption adjustment during the crisis can be explained by DM shocks), suggesting that leverage amplifies the role of global financial intermediaries transmitting shocks. However, global financial intermediaries still play a key role in systemic debt crises in an environment in which financial intermediaries are asset managers with zero leverage, but that still face financial frictions to raise external finance (governed by ϕ).

E.3.3. *The Role of Global Banks' Equity Issuance Cost, ϕ*

Table E5 shows the impact of the marginal cost of equity issuance, ϕ, on the composition of EM-spread risk premium. In particular, the exercise is to set ϕ to values below and above the baseline calibration, without recalibrating, and document the variation in the decomposition of risk. The case $\phi = 0$ resembles an economy without global banks, in line with such canonical models as Eaton and Gersovitz (1981) and Arellano (2008). The first panel shows the average spreads of decomposition, while the second panel presents its volatility. The main takeaway is

Table E3. Decomposing EM-Bond Spreads and Consumption Dynamics During the Global Financial Crisis: Calibration with Measured Endowment Processes

	ΔY_{EM}	ΔNW	Δ Spread	Δ C
Data	-2.14	-3.72	402	-1.72
Model				
Joint Shocks	-2.14	-4.09	493	-3.82
EM Shock Only	-2.14	-0.08	85	-1.5
DM Shock Only	0.0	-3.95	360	-2.12

Notes: Data figures (first line) correspond to the dynamics of variables of interest observed during the 2007–2009 period. ΔY_{EM} and ΔC refer to the change in the average cyclical component of GDP and consumption, respectively, in a sample of EMs (detailed in Appendix E.2) between 2009 and 2007. Cyclical components were computed with respect to a log-linear trend and standardized. ΔSpread refers to the change in the average of sovereign-bond spreads for the same sample of EM countries, in basis points. ΔNW corresponds to the change in the cyclical component of the market value of global banks' net worth, proxied by the stock price of publicly traded U.S. banks (XLF index), computed with respect to a log-linear trend and standardized. *Model* figures (lines 2–4) correspond to experiments in the alternative calibration of the model using systemic and idiosyncratic endowment processes measured in the data (see Section E.3.1). All variables in the model are expressed in the same units as in the data. *Joint Shocks* (line 2) corresponds to the dynamic response in the model to a sequence of shocks $\{\epsilon_{\omega t}, \epsilon_{\text{EM}t}\}$ that targets the dynamics of global banks' net worth and EMs' systemic endowment during 2007–2011 (similar to Figure 7 in our baseline calibration). The responses in the model were computed starting from the ergodic aggregate states. *EM shocks only* and *DM shocks only* (lines 3 and 4) correspond, respectively, to the response predicted in the model to just the sequence of shocks $\epsilon_{\text{EM}t}$ from the previous exercise and to just the sequence of $\epsilon_{\omega t}$ shocks from the previous exercise.

that financial frictions drive global banks' role in determining sovereign spreads, with higher costs of equity issuance being associated with a greater contribution of risk or intermediation premium on total spreads, for both the average and the standard deviation.

Table E4. Decomposing EM-Bond Spreads and Consumption Dynamics During the Global Financial Crisis: Calibration with $\kappa = 0$

	ΔY_{EM}	ΔNW	Δ Spread	Δ C
Data	-2.14	-3.72	402	-1.72
Model				
Joint Shocks	-2.14	-3.58	324	-2.12
EM Shock Only	-2.14	-0.13	108	-1.57
DM Shock Only	0.0	-3.43	162	-0.39

Notes: Data figures (first line) correspond to the dynamics of variables of interest observed during the 2007–2009 period. ΔY_{EM} and ΔC refer to the change in the average cyclical component of GDP and consumption, respectively, in a sample of EMs (detailed in Appendix E.2) between 2009 and 2007. Cyclical components were computed with respect to a log-linear trend and standardized. ΔSpread refers to the change in the average of sovereign-bond spreads for the same sample of EM countries, in basis points. ΔNW corresponds to the change in the cyclical component of the market value of global banks' net worth, proxied by the stock price of publicly traded U.S. banks (XLF index), computed with respect to a log-linear trend and standardized. *Model* figures (lines 2–4) correspond to experiments in the alternative calibration of the model with $\kappa = 0$ (see Section E.3.2). All variables in the model are expressed in the same units as in the data. *Joint Shocks* (line 2) corresponds to the dynamic response in the model to a sequence of shocks $\{\epsilon_{\omega t}, \epsilon_{\text{EM}t}\}$ that targets the dynamics of global banks' net worth and EMs' systemic endowment during 2007–2011 (similar to Figure 7 in our baseline calibration). The responses in the model were computed starting from the ergodic aggregate states. *EM shocks only* and *DM shocks only* (lines 3 and 4) correspond, respectively, to the response predicted in the model to just the sequence of shocks $\epsilon_{\text{EM}t}$ from the previous exercise and to just the sequence of $\epsilon_{\omega t}$ shocks from the previous exercise.

TABLE E5. Equity Issuance Costs and Unconditional Decomposition of EM-Bond Spreads

	Baseline	Equity Cost			
		$\phi = 0.0$	$\phi = 0.9$	$\phi = 2.0$	$\phi = 8.0$
(A) Average					
Total Spread	404bp	285bp	405bp	398bp	398bp
Default Premium	295bp	285bp	339bp	307bp	272bp
Risk Premium	109bp	0bp	66bp	90bp	127bp
Contribution Risk Premium	27.1%	0.0%	16.3%	22.7%	31.8%
(B) Standard Deviation					
Total Spread	166bp	139bp	178bp	168bp	157bp
Default Premium	137bp	139bp	156bp	141bp	122bp
Risk Premium	91bp	0bp	85bp	88bp	91bp
Contribution Risk Premium	54.9%	0.0%	47.4%	52.4%	58.1%

Notes: This table shows a decomposition of the model's predicted EM-bond spreads into their default- and risk-premium components for different values of global banks' costs of raising equity, ϕ. The model's other parameters are those detailed in Section 4.1. We define the default-premium component of spreads as the bond spreads that would be observed, given EMs' equilibrium sequence repayment and borrowing policies, if debt were priced by a risk-neutral lender. To compute the default-premium component of spreads, we compute a sequence of risk-neutral prices, $\tilde{q}^i_{\text{EM}t} = \mathbb{E}_t\left[\beta_{\text{DM}}\iota_{it+1}\left(1+\xi\tilde{q}^i_{\text{EM}t+1}\right)\right]$, where $\{\iota_{it}\}_{t=0}^{\infty}$ denotes the sequence of state-contingent repayment policies from our baseline economy. We then compute EM yields to maturity based on risk-neutral prices $\{\tilde{q}^i_{\text{EM}t}\}_{t=0}^{\infty}$. We define the risk premium as the difference between the spreads predicted by the model and the default-premium component. Panel (A) shows the unconditional average of each variable and Panel (B) the unconditional volatility.