

SUPPLEMENT TO “GLOBAL BANKS AND SYSTEMIC DEBT CRISES”
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APPENDIX SA: 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 parameterization of the model that targets cross-sectional empirical estimates from the data delivers quantitative results similar to those in the baseline model.

SA1. *Model*

Our secondary market model introduces short-run trading frictions that can account for the patterns observed in the data. We model this by introducing two additional features to the environment. 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. In the second subperiod, risky securities are repaid and 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 additional feature is the existence of trading networks in the secondary market. We introduce trading networks with two assumptions. First, we assume that each EM economy and DM nonfinancial firm issues different varieties of bonds, indexed by ℓ , that have the same repayment but will feature different holders in equilibrium. Second, we assume that banks specialize in a particular variety and trade securities of that variety issued by any EM economy and DM firm.

These new features allow the model to exhibit the same variation found in the empirical analysis—namely, multiple bonds issued by the same borrower with different holders—and also give rise to the possibility of bonds with similar characteristics having different prices in the secondary market. The presence of varieties of securities in which banks specialize gives rise to banks displaying different portfolios of bonds with similar default risk, liquidity properties, and other relevant characteristics, which persist over time; this is

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consistent with the facts documented in Section 3. Additionally, the assumption of trading networks is aimed at capturing the idea that in the short run. Capital is slow moving; this may be due to the presence of search costs for trading counterparties, information frictions, or time to adjust portfolios, which potentially leads to limits to arbitrage (see, e.g., [Duffie \(2010\)](#), [Lagos, Rocheteau, and Wright \(2017\)](#), and references therein).

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

$$\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta_{\text{DM}}^{s-t} \pi_{jt+s}. \quad (35)$$

A bank j that specializes in variety ℓ arrives at the period t secondary market with a portfolio of EM securities $\{a_{\text{EM}j,t-1}^i(\ell)\}_{i \in \mathcal{I}_{t-1}}$, DM securities $a_{\text{DM}j,t-1}(\ell)$, and deposits $d_{j,t-1}$ acquired in the primary market at $t-1$. Secondary markets are segmented by variety: Banks can only trade with others that specialize in the same variety at prices $\{q_{\text{EM}j,t}^i(\ell)\}_{i \in \mathcal{I}_t}$ for EM securities and $q_{\text{DM}j,t}^0(\ell)$ for DM securities. This implies that the index ℓ denotes both a particular variety of EM and DM security and a particular trading network. 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. The value of the net worth in the secondary market is given by

$$n_{jt}^0 = \int_{i \in \mathcal{I}_{t-1}} q_{\text{EM}j,t}^i(\ell) a_{\text{EM}j,t-1}^i(\ell) di + q_{\text{DM}j,t}^0(\ell) a_{\text{DM}j,t-1}(\ell) - R_d d_{j,t-1}. \quad (36)$$

In the secondary market, banks can purchase existing securities $(a_{\text{DM}j,t}^0(\ell), \{a_{\text{EM}j,t}^i(\ell)\}_{i \in \mathcal{I}_{t-1}})$, issue equity div_{jt}^0 , and issue new deposits d_{jt}^0 to be repaid in the period t primary market. Their flow of funds constraint in the secondary market is given by

$$n_{jt}^0 + d_{jt}^0 = \int_{i \in \mathcal{I}_t} q_{\text{EM}j,t}^i(\ell) a_{\text{EM}j,t}^i(\ell) di + q_{\text{DM}j,t}^0(\ell) a_{\text{DM}j,t}^0(\ell) + div_{jt}^0. \quad (37)$$

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 the repayment associated with each of these securities

$$n_{jt} = \int_{i \in \mathcal{I}_{t-1}} R_{\text{EM}j,t}^i(\ell) q_{\text{EM}j,t}^i(\ell) a_{\text{EM}j,t}^i(\ell) di + R_{\text{DM}j,t}^0(\ell) q_{\text{DM}j,t}^0(\ell) a_{\text{DM}j,t}^0(\ell) - R_d^0 d_{jt}^0, \quad (38)$$

where $(\{R_{\text{EM}j,t}^i(\ell)\}_{i \in \mathcal{I}_{t-1}}, R_{\text{DM}j,t}^0(\ell))$ 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_d^0 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 $(a_{\text{DM}j,t}(\ell), \{a_{\text{EM}j,t}^i(\ell)\}_{i \in \mathcal{I}_{t-1}})$, issue equity div_{jt} , and issue new deposits d_{jt} to be repaid in the period $t+1$ secondary market. Its flow of funds constraint in the primary market is given by

$$n_{jt} + d_{jt} = \int_{i \in \mathcal{I}_t} q_{\text{EM}j,t}^i(\ell) a_{\text{EM}j,t}^i(\ell) di + q_{\text{DM}j,t}(\ell) a_{\text{DM}j,t}(\ell) + div_{jt}. \quad (39)$$

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

$$d_{jt}^0 \leq \kappa n_{jt}^0 \quad \text{and} \quad d_{jt} \leq \kappa n_{jt}, \quad (40)$$

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

$$\pi_{jt} = \text{div}_{jt}^0 (1 + \mathbb{I}_{\text{div}_{jt}^0 < 0} \mathcal{C}(\text{div}_{jt}^0, n_{jt}^0)) + \text{div}_{jt} (1 + \mathbb{I}_{\text{div}_{jt} < 0} \mathcal{C}(\text{div}_{jt}, n_{jt})). \quad (41)$$

Finally, each subperiod experiences an i.i.d. exit shock that occurs with probability $1 - \sigma$ in primary markets and $1 - \sigma^0$ in secondary markets, with $\sigma = \sigma^0$ in the calibrated model. Banks that exit repay outstanding deposits, sell their securities in the relevant market, and transfer the net proceedings to their owners. In each subperiod, a mass of new banks equal to the exit probability 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 \bar{n} and \bar{n}^0 in the primary market and secondary market, respectively. Aggregating banks within a trading network, we obtain an expression for net worth in the secondary market stage at the trading network level:

$$N_t^0(\ell) = \sigma \left[\int_{i \in \mathcal{I}_{t-1}} q_{EMt}^i(\ell) A_{EMt-1}^i(\ell) di + q_{DMt}^0(\ell) A_{DMt-1}(\ell) - R_d D_{t-1}(\ell) \right] + (1 - \sigma) \bar{n}_0, \quad (42)$$

where the variables in capital letters with a dependence on ℓ refer to the aggregate counterparts for the trading network ℓ .

The problem of global bank j specializing in variety ℓ is to choose state-contingent plans $\{(a_{EMjt}^i(\ell), a_{EMjt+1}^i(\ell))_{i \in [0, \mu_{EM}]}, a_{DMjt}^0(\ell), a_{DMjt}(\ell), \text{div}_{jt}^0, \text{div}_{jt}, d_{jt}^0, d_{jt}\}_{t=0}^\infty$ to maximize (7) subject to flow of funds and financial constraints (36)–(41). The bank's problem is characterized by asset-pricing conditions for the secondary and primary market:

$$R_{EMt}^{i0}(\ell) = R_{DMt}^0(\ell), \quad (43)$$

$$\mathbb{E} \left[\nu_{t+1}^0(\ell) \frac{q_{EMt+1}^i(\ell)}{q_{EMt}^i(\ell)} \right] = \mathbb{E} \left[\nu_{t+1}^0(\ell) \frac{q_{DMt+1}^0(\ell)}{q_{DMt}^0(\ell)} \right] \equiv R_t^e(\ell), \quad (44)$$

for all ℓ and securities i with positive investments, where $\nu_{t+1}^0(\ell)$ is the marginal value of net worth of a bank specializing in variety ℓ in secondary markets of period $t + 1$.¹ The first equation states that required returns from holding any security of a given variety

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

$$\nu_t^0(\ell) = (1 - \sigma^0) + \sigma^0 \max \left\{ \frac{1}{4\phi} (\nu_t R_d^0 - 1)^2 + \nu_t R_d^0; \frac{1}{4\phi} (\nu_t R_{DMt}^0(\ell) - 1)^2 + \nu_t [R_{DMt}^0(\ell)(1 + \kappa) - \kappa R_d^0] \right\},$$

from secondary to primary markets are the same.² 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 debt financing are characterized by the following complementary slackness conditions:

$$(R_t^e(\ell) - \mathbb{E}[\nu_{t+1}^0(\ell)]R_d)(\kappa n_{jt} - d_{jt}) = 0 \quad \text{and} \quad (R_{DMt}^0(\ell) - R_d^0)(\kappa n_{jt}^0 - d_{jt}^0) = 0. \quad (45)$$

These equations state that the borrowing constraint will bind whenever the expected risk-adjusted returns on assets exceed those from deposits. The optimal equity choices are given by³

$$-2\phi\left(\frac{div_{jt}}{n_{jt}}\right) = \beta_{DM}R_t^e(\ell) - 1 \quad \text{and} \quad -2\phi\left(\frac{div_{jt}^0}{n_{jt}^0}\right) = \nu_t R_{DMt}^0(\ell) - 1. \quad (46)$$

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

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 $R_d^0 = 1$.

The EM economy faces a problem that is similar to that in the baseline economy, with the only difference being that it can choose to issue debt of different varieties $b_{EMt+1}(\ell)$ 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.⁴ The EM budget constraint under repayment is given by

$$c_{it} = y_{EMt} + z_{it} + \int [q_{EMt}^i(\ell)(b_{it+1}(\ell) - \xi b_{it}(\ell)) - b_{it}(\ell)] d\ell. \quad (47)$$

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

$$q_{EMt}^i(\ell) = q_{EMt}^i(\ell'), \quad (48)$$

$$\nu_t = (1 - \sigma) + \sigma \max\left\{\frac{1}{4\phi}(\mathbb{E}[\nu_{t+1}^0(\ell)] - 1)^2 + \mathbb{E}[\nu_{t+1}^0(\ell)];$$

$$\frac{1}{4\phi}\left(\beta_{DM}\mathbb{E}\left[\nu_{t+1}^0(\ell)\frac{q_{DMt+1}^0(\ell)}{q_{DMt}^0(\ell)}\right] - 1\right)^2 + \beta_{DM}\left(\mathbb{E}\left[\nu_{t+1}^0(\ell)\frac{q_{DMt+1}^0(\ell)}{q_{DMt}^0(\ell)}\right](1 + \kappa) - \mathbb{E}[\nu_{t+1}^0(\ell)]R_d\kappa\right)\right\}.$$

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

²In this case, since there is no uncertainty between secondary and primary markets, required returns are equal to realized returns.

³These choices are in those states in which the return of injecting one additional unit of equity in the banks and investing it in risky assets is larger than the inverse of the DM discount factor, that is, the right-hand sides of (46) are positive. Note that in the optimal equity choice in the secondary market, the relevant DM discount factor is one. We focus on parameterizations in which this condition always holds.

⁴This assumption is motivated by the fact that cross-default clauses in bonds prevent discriminatory defaults on different securities, especially when issued in the same market.

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 $b_{it+1} = \int b_{it+1}(\ell) d\ell$. The split of total debt between varieties is determined by the demand for securities, since each EM household is indifferent between issuing any of them.

Nonfinancial DM firms face the same problem as in the baseline model, but with the difference that they can issue securities of different varieties and they only make decisions in the primary-market subperiod. Similar to EM economies, in equilibrium, prices of the DM securities for different varieties in the primary market will be the same. Additionally, if we assume that the aggregate amount of DM securities is equal to the capital stock, $A_{DMt} = k_{t+1}$, then the prices of the securities will be equal to one, $q_{DMt}^i(\ell) = 1$, for all ℓ .

Finally, we define returns and EM bond prices in equilibrium. Returns from holding securities from secondary markets until primary markets are given by $R_{EMt+1}^{i0}(\ell) = \frac{v_{it+1}(1+\xi)q_{EMt+1}^i(\ell)}{q_{EMt}^0(\ell)}$ and $R_{DMt+1}^0(\ell) = \frac{\omega_{t+1}[\alpha A_{DMt}^{\alpha-1} + 1 - \delta]}{q_{DMt}^0(\ell)}$. The price of EM bonds in primary markets is given by $q_{EMt}^i(\ell) = \frac{\mathbb{E}[v_{it+1}(\ell)q_{EMt+1}^i(\ell)]}{R_{t+1}^e(\ell)}$.

DEFINITION 1: Given global banks' initial portfolios $((a_{EMj0}^i(\ell))_{i \in [0, \mu_{EM}]}, a_{DMj0}(\ell), d_{j,0})_{j \in [0,1]}_{\ell \in [0,1]}$, EM households' initial debt positions $(b_{i0})_{i \in [0, \mu_{EM}]}$, and state-contingent processes $\{\omega_t, y_{EMt}, (z_{it}, \psi_{it})_{i \in [0, \mu_{EM}]}\}_t$, a competitive equilibrium in the global economy is a sequence of prices $\{(w_t, (q_{EMt}^{i0}(\ell), q_{EMt}^i(\ell))_{i \in [0, \mu_{EM}]}, q_{DMt}^0(\ell), q_{DMt}^\infty)_{\ell=0}^\infty\}_{t=0}^\infty$ and allocations for DM households $\{c_{DMt}, d_{t+1}^0, d_{t+1}\}_{t=0}^\infty$, EM households $\{(c_{it}, b_{it+1}(\ell), v_{it})_{\ell \in [0,1]}_{i \in [0, \mu_{EM}]}\}_{t=0}^\infty$, nonfinancial firms $\{h_t, k_{t+1}\}_{t=0}^\infty$, and global banks $\{((a_{EMjt+1}^{i0}(\ell), a_{EMjt+1}^i(\ell))_{i \in [0, \mu_{EM}]}, a_{DMjt+1}^0(\ell), a_{DMjt+1}(\ell), d_{jt+1}^0, d_{jt+1}, div_{jt}^0, div_{jt})_{j \in [0,1]}\}_{\ell=0}^\infty_{t=0}^\infty$ such that:

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

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

$$\int_{j \in \mathcal{J}(\ell)} q_{EMt}^i a_{EMjt}^i(\ell) dj = q_{EMt}^i b_{it+1}(\ell), \quad (49)$$

$$\int_{\ell \in [0,1]} \int_{j \in \mathcal{J}(\ell)} q_{DMt}(\ell) a_{DMjt}(\ell) dj d\ell = k_{t+1}. \quad (50)$$

Equation (49) refers to the 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 (50) refers to market clearing of the DM risky security. Market clearing in the secondary market of trading network ℓ implies

$$\int_{j \in \mathcal{J}(\ell)} q_{EMt}^{i0} a_{EMjt}^{i0}(\ell) dj = \int_{j \in \mathcal{J}(\ell)} q_{EMt}^{i0} a_{EMjt-1}^i(\ell) dj, \quad (51)$$

$$\int_{j \in \mathcal{J}(\ell)} q_{DMt}^0(\ell) a_{DMjt}^0 dj = \int_{j \in \mathcal{J}(\ell)} q_{DMt}^0(\ell) a_{DMjt-1} dj. \quad (52)$$

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 the 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 and DM firm can issue any variety prevents these price differences' persistence.

SA2. Financial Frictions and Secondary-Market Elasticity

This section illustrates how the secondary-market elasticity of bond yields to banks' net worth is informative of the degree of financial frictions faced by banks. 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, as noted in (46), optimal equity issuance is increasing in returns. 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 Supplementary Material Figure SA1.

Consider now a trading network composed of more distressed banks that have lower net worth due to a lower share of retained earnings $\sigma^0(\ell)$. 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 by the dotted line in Supplementary Material Figure SA1(a), and increases the equilibrium required return. The net worth of banks in this trading network also falls, since all of their assets are now worth less.

How much secondary market prices respond to shocks to $\sigma^0(\ell)$ 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 Supplementary Material Figure SA1(a), a shock to $\sigma^0(\ell)$ will be associated with a large drop in price, 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 issue equity; therefore, prices and returns need to respond less to the same magnitude shock to $\sigma^0(\ell)$ to induce equity issuance

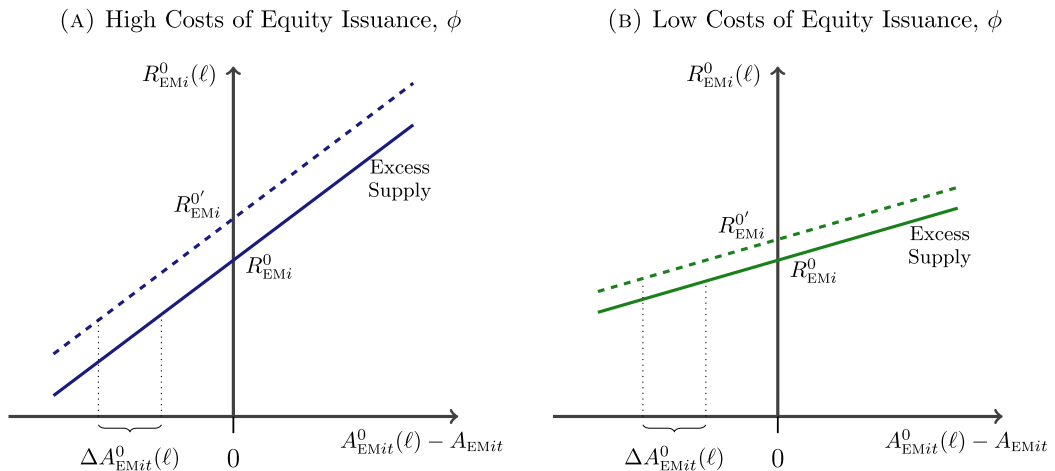


FIGURE SA1.—Equilibrium in the Secondary Market.

TABLE SAI
MODEL WITH SECONDARY MARKETS: MODEL AND DATA MOMENTS.

Target	Data	Model
Average EM debt	15.0%	13.2%
EM default frequency	1.5%	1.3%
Average EM-bond spreads	410 bp	497 bp
Volatility of EM-bond spreads	173 bp	138 bp
Correlation between EM-bond spreads and endowment	-31%	-85%
Volatility of global banks' net worth (NW)	0.28	0.21
Correlation between global banks' NW and systemic EM endowment	40%	39%
Share of EM securities in global banks' total risky assets	10%	10%
Secondary market cross-sectional semi-elasticity EM spreads to banks' NW	0.056	0.057
Global banks' total-assets-to-equity ratio	3.8	4.3
Global banks' assets returns from secondary to primary markets stages	1	1.01
Primary market aggregate semi-elasticity EM spreads to banks' NW	0.056	0.031

Note: 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. Supplementary Material SB2 details the sample and data sources. Data moments on global banks' net worth were computed using the cyclical component in the stock price of publicly traded US 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 on individual banks' balance sheets in the sample of banks from our empirical section (detailed in Appendix Table CI) with aggregate data on debt position. 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 Supplementary Material SA for a detailed discussion of the model counterpart of this data object.

and restore equilibrium. This can be seen in Supplementary Material Figure SA1(b). 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.

SA3. 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 fraction of earnings that are retained at each trading network. This shock is introduced with a mean-preserving spread to the parameter $\sigma^0(\ell)$, and can capture differential initial levels of capitalization due to bank-specific runs or exogenous recapitalizations. 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.

We then use this model to quantitatively reproduce the empirical analysis from Section 3 in model-simulated data. The objective is to show that a parameterization that targets the cross-sectional elasticity estimated from the data generates quantitative results that are in line with those of the baseline model. We parameterize this model by calibrating the same set of moments as in the baseline model, with the main difference being that instead of targeting the aggregate elasticity, we now target the cross-sectional elasticity from the secondary markets.⁵ The targeted moments are reported in Supplementary Material Table SAI.

⁵This model also features one parameter, $\bar{\pi}^0$, that is not in the baseline model. We calibrate it so that the within-period average return from holding risky debt from the secondary market to the primary market is one.

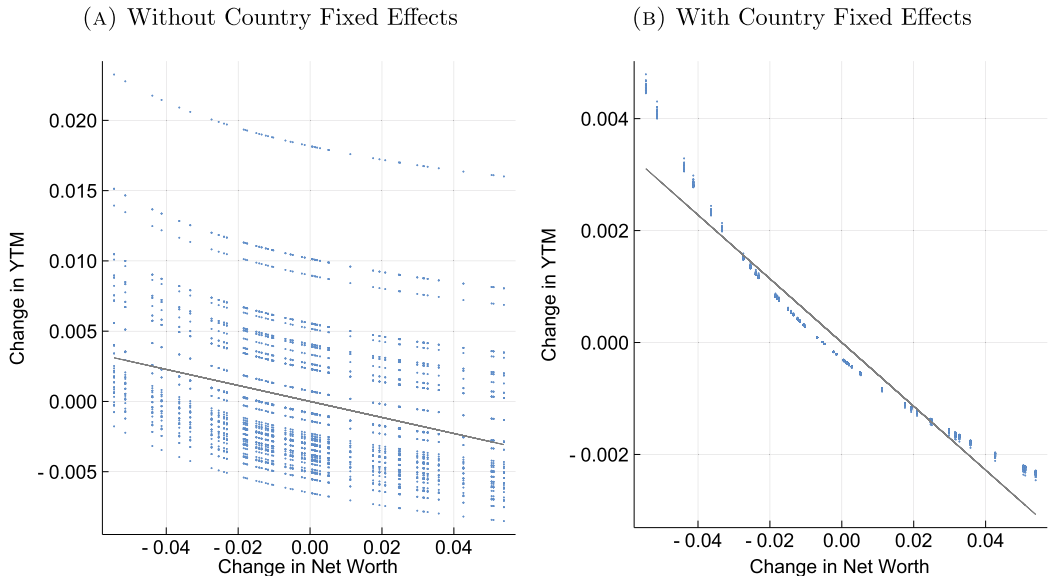


FIGURE SA2.—Change in Yield to Maturity and Holders' Net Worth: Model-simulated Data. *Notes:* Panel (A) shows the model-simulated data on changes in bond-yield and in the log market value of net worth. The horizontal axis includes the demeaned change in net worth for each variety (and trading network). 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 the country-average change in yields.

To compute the cross-sectional elasticity, we feed into the model a shock to ω such that banks' aggregate net worth falls by the same amount as it did in the window around the Lehman episode (see Table I), together with unexpected idiosyncratic shocks to the capitalization of banks in different trading networks. In order to generate dispersion across trading networks, we simulate various $\sigma^0(\ell)$ from a lognormal distribution with mean 0.71 (which is the calibrated value σ^0 in the model) and standard deviation 0.13. We calibrate the standard deviation 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 residualized fall in net worth per bond in the empirical section, 7%. We then compute yields to maturity (obtained from secondary-market prices) of 50 varieties of bonds from 60 countries in the model, maintaining the share of average bonds per country found in the data. We also compute the log-change in the market value of net worth in each of the 50 trading networks that trade different varieties. Supplementary Material Figure SA2(a) shows the raw simulated data, with the demeaned change in net worth at the variety/trading-network level on the horizontal axis and the demeaned change in yields on the vertical axis. The negative 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 the default risk that comes from different borrowers. Once this borrower heterogeneity is filtered out with fixed effects, the

This moment is introduced to capture the high-frequency notion of the secondary market subperiod in which there is no time discounting and zero net returns.

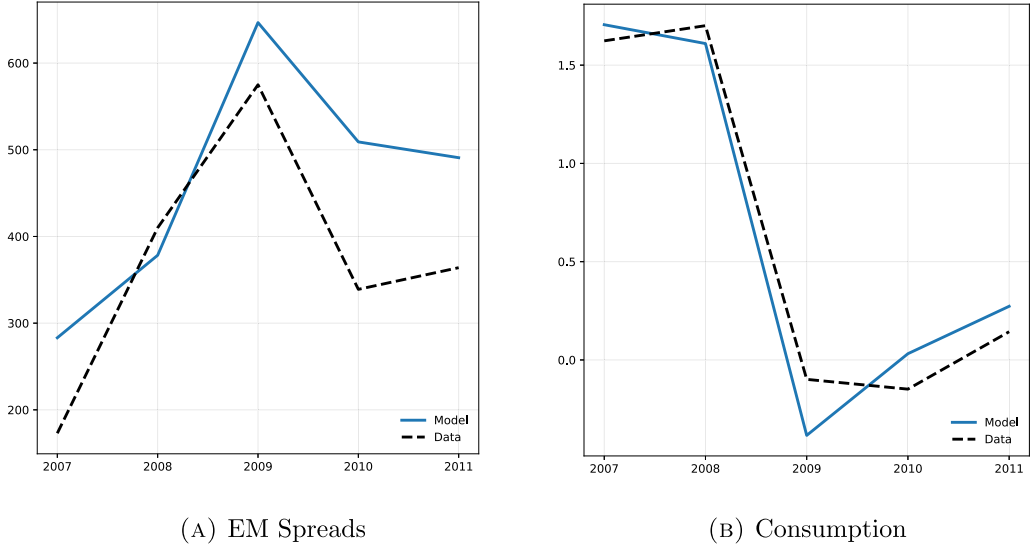


FIGURE SA3.—Response in the Secondary-markets Model During the Lehman Episode. *Notes:* *Data* (dashed lines) refers to the average of sovereign-bond spreads (in bps) and the cyclical component of consumption (standardized) in a sample of EMs (see Supplementary Material SB2). *Model* (solid lines) refers to the response of the variables to a sequence of shocks $\{\epsilon_{\omega t}, \epsilon_{EMt}\}$ that targets the dynamics of global banks' net worth and EMs' systemic endowment during 2007–2011 (see Figure SB2).

change in net worth accounts for most of the residual change in yields (see Supplementary Material Figure SA2(b)).

We then estimate the regression on model-simulated data:

$$\Delta ytm_{i\ell}^0 = \alpha_i + \eta_{xs} \Delta \log V^0(N_\ell^0) + \epsilon_{i\ell}, \quad (53)$$

where $\Delta ytm_{i\ell}^0$ is the within-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 $\sigma^0(\ell)$; α_i is a borrower fixed effect; $\Delta \log V^0(N_\ell^0)$ is the change in the aggregate log market value of net worth of banks that trade variety ℓ . This regression is equivalent to the empirical regression (17) without controls, as these are not featured in the model. The estimated cross-sectional elasticity is $\eta_{xs} = -0.057$, which is close to the empirical target.

We then compute the elasticity at the aggregate level as a nontargeted moment, computed as in our baseline model. The untargeted aggregate elasticity is -0.031 (see last row of Supplementary Material Table SAI), which is negative but slightly smaller in absolute value than the cross-sectional elasticity. The quantitative differences between the cross-sectional and aggregate elasticity are due to differences in the supply of bonds in primary and secondary markets. In secondary markets, the supply of outstanding bonds is fixed from the previous period. In primary markets, the supply of bonds (or equivalently, the demand of funds) comes from solving the EM households' problem and is decreasing in the required returns. The presence of this downward-sloping demand of funds attenuates the aggregate elasticity relative to the cross-sectional one, which is computed purely from the price dynamics in the secondary markets.

SA4. *Aggregate Quantitative Results*

This section summarizes the main quantitative aggregate results in the model with secondary markets. We first recompute the exercise that analyzes the dynamics of spreads and consumption during the global financial crisis in this version of the model. Supplementary Material Figure SA3 shows that the dynamics of these variables are similar to those observed in the data. In addition, the conditional decomposition of shocks in this model still suggests a major role of DM shocks in explaining the dynamics of spreads. Finally, we also perform the unconditional decomposition of spreads in this model and find that the intermediation premium accounts for roughly one-third of the fluctuations in spreads. These results suggest that the calibrated model with secondary markets delivers quantitative results that are similar to those observed in the baseline model. Results are available upon request.

APPENDIX SB: QUANTITATIVE ANALYSIS

SB1. *Solution Method*

As discussed in Appendix A1, our model's agent 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 the information from 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 features of our model. First, an individual EM's problems involve a default choice without commitment, which requires the use of global methods in the solution 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 summary statistics as part of the state variables in the agents' individual problems.⁶ 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 for banks' DM-firm-invested assets, $\hat{A}_{DM}(s)$, which governs DM firms' marginal product of capital. In equilibrium, perceived policies must coincide with actual policies. To avoid inaccuracies originating from this perceived policy function, we allow for an auxiliary aggregate variable \hat{A}_{DM} —which describes aggregate investment in DM firms at the end of the period—as a state variable in agents' individual problems. Using \hat{A}_{DM} as a state also has the advantage that the approximate solution is always consistent with market clearing.

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

$$\begin{aligned} v(s_x) = & (1 - \sigma) + \sigma \max \left\{ \frac{1}{4\phi} (\mathbb{E}[v(s'_x)] - 1)^2 + \mathbb{E}[v(s'_x)]; \right. \\ & \left. \frac{1}{4\phi} (\beta_{DM} \mathbb{E}[v(s'_x) R_{DM}(s'_x, s_x)] - 1)^2 + \beta_{DM} (\mathbb{E}[v(s'_x) R_{DM}(s'_x, s_x)])(1 + \kappa) \right\} \end{aligned}$$

⁶The relevance of the degree of aggregate uncertainty in our model causes us to 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.

$$- \mathbb{E}[\nu(s'_x)]R_d\kappa \Big\} \quad (54)$$

$$\hat{A}'_{DM} = \mathcal{F}_A(s_x, \hat{A}_{DM}), \quad (55)$$

where $\mathcal{F}_A(\cdot)$ denotes the forecasting rule assumed to be used by agents under the approximate solution and s_x is the exogenous aggregate state.

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

$$V(b, z, s_x, \hat{A}_{DM}) = \max_{\iota} \iota V^r(b, z, s_x, \hat{A}_{DM}) + (1 - \iota) V^d(z, s_x, \hat{A}_{DM}), \quad (56)$$

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

$$V^r(b, z, s_x, \hat{A}_{DM}) = \max_{b'} u(c) + \beta \mathbb{E}[V(b', z', s'_x, \hat{A}'_{DM})], \quad (57)$$

$$\text{s.t. } c = y_{EM} + z - b + q(b', z, s_x, \hat{A}_{DM})(b' - \xi b), \quad (55),$$

$$q(b', z, s_x, \hat{A}_{DM}) = \frac{\mathbb{E}[v(s'_x, \hat{A}'_{DM})\tilde{v}(b', z', s'_x, \hat{A}'_{DM})(1 + \xi q(b'', z', s'_x, \hat{A}'_{DM}))]}{\mathbb{E}[v(s'_x, \hat{A}'_{DM})R_{DM}(s'_x, \hat{A}'_{DM})]},$$

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

$$V^d(z, s_x, \hat{A}_{DM}) = u(c) + \beta \mathbb{E}[\phi V^r(0, z', s'_x, \hat{A}'_{DM}) + (1 - \phi) V^d(z', s'_x, \hat{A}'_{DM})], \quad (58)$$

$$\text{s.t. } c = \mathcal{H}(y_{EM} + z), \quad (55).$$

For the forecasting rule, $\mathcal{F}_A(\cdot)$, our benchmark algorithm follows [Krusell and Smith \(1998\)](#) in parameterizing an assumed functional form for the rule and using an iterative procedure with model-simulated data to estimate the parameters of the functional form. To render the procedure parsimonious, we assume a log-linear forecasting rule in $\{\omega, \hat{A}_{DM}\}$ and reduce the aggregate state space to (s_x, \hat{A}_{DM}) .⁷ 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 $\mathcal{F}_A^{j+1}(\cdot)$. Defining $\mathcal{F}^j(\tilde{s}_x)$ as 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 forecasting rule and iterate in steps (2) and (3) for $j = 1, 2, 3, \dots$, until δ_{j+1} is sufficiently small.

⁷Borrowers only need (s_x, \hat{A}_{DM}) to infer current required returns. Adding moments related to the joint distribution of assets could potentially improve forecastability, but we find that first moments of debt and deposits do not make significant improvements and would be subject to the curse of dimensionality. Considering richer forecasting rules leads to convergence problems in the iterative procedure.

In each period t of the simulation, we need to evaluate whether the borrowing constraint binds. We start by guessing that the constraint does not bind. This requires finding the policy \bar{A}_{DM} such that $R_{DM}^e(\mathbf{s}) = \mathbb{E}[\nu(\mathbf{s}')]R_d$, evaluating borrowers' policies, computing lenders' dividends from the optimality condition and deposits from the flow of funds constraint, and checking whether $\frac{d}{R_d} < \kappa N$. If this is the case, we find that period's solution and move on to the next period. If not, we find A_{DM}^* such that markets clear when the borrowing constraint is binding.

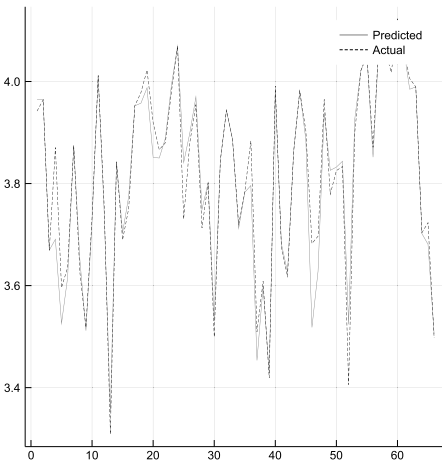
We analyze the goodness-of-fit of the assumed forecasting rule following Den Haan (2010), who suggests testing the accuracy of the forecast rule by performing a multiperiod forecasting without updating the endogenous state variable. This method does not adjust for deviations from the true endogenous state, and thus provides 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}_{DM} and compare it with a series of bond prices under the multiperiod forecast of the policy \hat{A}_{DM}^f . The steps are as follows:

- (1) Draw a sample for the exogenous processes s_x .
- (2) Solve for the equilibrium prices and allocations in each period. In particular, obtain a realization for $\{\hat{A}_{DM,t}\}_{t=1}^T$.
- (3) Let $\hat{A}_{DM,0}^f = \hat{A}_{DM,0}$ and construct $\hat{A}_{DM,t}^f = \mathcal{F}_A(\omega_t, \hat{A}_{DM,t-1}^f)$.
- (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 $\{\hat{A}_{DM,t}\}_{t=1}^T$ and a series of bond prices $\{q_t^f\}_{t=1}^T$ using $\{\hat{A}_{DM,t}^f\}_{t=1}^T$.

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

The R^2 of the series is 97%. Supplementary Material Figure SB1 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 the accumu-

(A) Actual Versus Predicted



(B) Density of Log Residuals

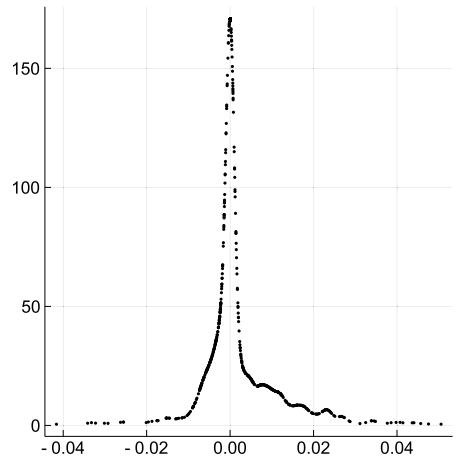


FIGURE SB1.—Fundamental Accuracy Plot. *Notes:* The left panel shows a subset of the time series of the actual and forecasted versions of the bond price for a simulated individual economy. The right panel shows the estimated density of the log residuals for the entire sample. On the x -axis, we have the value for the log residual and on the y -axis the density value.

lation of errors over time. The predicted series closely follows the actual series for bond prices, which suggests that the main driver for the DM policy is the ω shock. In addition, the residuals are centered around zero most of the time, although mildly skewed; 65% of the absolute values of the log residuals are less than 0.5%; 81% are less than 1%; and 96% are less than 2.5%.

SB2. *Data Used in Quantitative Analysis*

SB2.1. *EM Country Data*

Our sample consists of the following countries: Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Ecuador, El Salvador, Hungary, Indonesia, Jamaica, Latvia, Lithuania, Malaysia, Mexico, Morocco, Pakistan, Panama, Peru, Philippines, Poland, Russia, South Africa, Thailand, Turkey, Ukraine, and Venezuela. For all countries in the sample, we collect data on sovereign spreads, 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 Datastream. Data on real GDP, real consumption, and trade balance ratio were obtained from national sources and the IMF. The sample period is from 1994 to 2014, but data on particular countries may have different starting and ending points, depending on availability.

SB2.2. *Global Banks' Net Worth*

The data moments on global banks' net worth were computed using the cyclical component in the stock price of publicly traded US banks that have data coverage for the period of analysis (tracked by the XLF index).

We also obtain institution-level data to compute two key moments of the calibration: the leverage of financial intermediaries and their estimated exposure to EM debt. We obtain the data used in these estimates from the intermediaries' annual reports (from AnnualReports.com), which include balance-sheet information and off-balance-sheet information on assets under management.

We compute two measures of leverage. The first measure corresponds to the "book value" of leverage, which is defined as the ratio of total assets to total equity. The second measure, which we label "AUM adjusted leverage," incorporates assets under management in the measurement of leverage. In particular, it is defined as the ratio of the sum of total assets in the institution's balance-sheet and assets under management to the sum of total equity in the balance-sheet and assets under management. We compute this measure because, in our model, financial intermediaries are aimed at capturing a consolidated entity that maximizes the joint value of the owners' equity in the firm and the owners of the assets under management. Table CII reports the two measures of leverage for 28 financial intermediaries in our sample for the year 2006. On average, the book value of leverage is 19 and the adjusted leverage is 3.8.

To estimate the exposure of total assets to EM debt, we proceed in two steps. In the first step, we identify government and private-sector securities reported in the institution's assets side of the balance-sheet that are disaggregated by country. For example, HSBC reports the holdings of government bonds issued by the US, UK, Hong Kong, and other governments. The second step consists of estimating how much of the share of the other governments' debt holdings can be attributed to emerging markets and how much

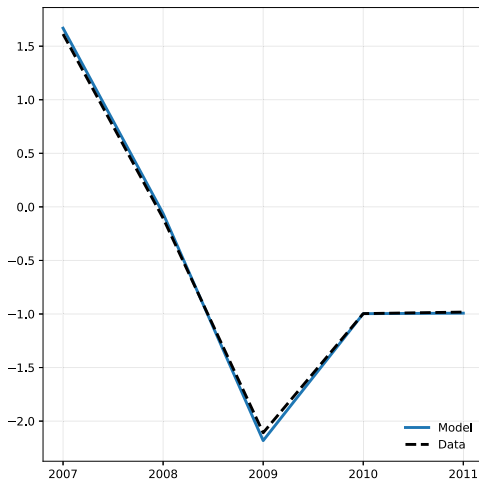
to advanced economies that are not the US, UK, or Hong Kong. We estimate this by using WEO data; in particular, we distribute the holdings of other governments' debt according to the ratio of emerging-market government debt to the sum of emerging-market government debt and that from advanced economies that are not the US, UK, or Hong Kong.

Formally, denote N_{EM} and N_{DM} the set of emerging and advanced economies. Denote $N_j \subseteq N_{DM}$ the set of advanced economies for which bank j reports disaggregated data; $\{(d_{ji})_{i \in N_j}\}$ the amount of holdings by institution j of bonds issued by government i ; and D_j the total government debt holdings by institution j . We can compute the holdings of other nonreported governments as $d_{j,other} \equiv D_j - \sum_{i \in N_j} d_{ji}$. Finally, let d_i^{WEO} denote the outstanding debt of government i in the WEO data set. We then estimate the share of EM holdings by institution j as $s_{jEM} = \frac{d_{j,other} \sum_{i \in N_{EM}} d_i^{WEO}}{D_j \sum_{i \notin N_j} d_i^{WEO}}$.

Finally, we follow a similar procedure for estimating intermediaries' exposure to private EM securities. Table CI reports the estimated exposure of 25 financial intermediaries in our sample for the year 2006, with an average of 10%.

SB3. Additional Quantitative Results From the Baseline Model

(A) Global Banks' Net Worth



(B) EMs' Systemic Endowment

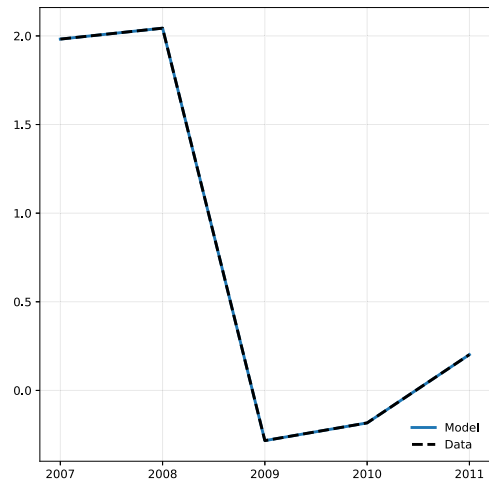
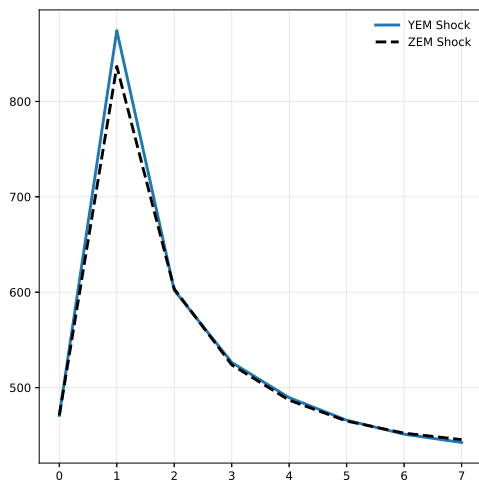
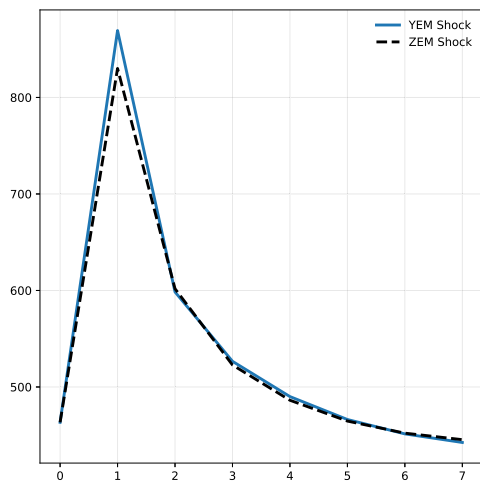


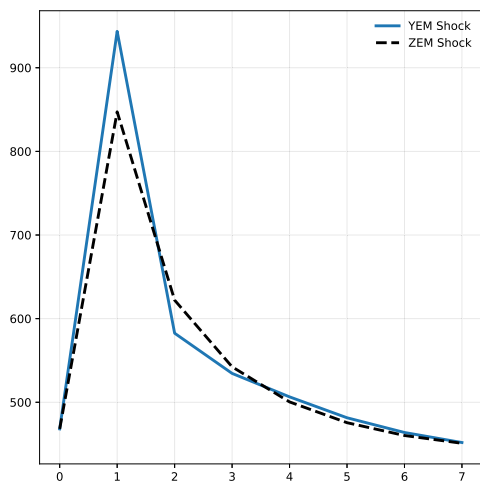
FIGURE SB2.—Global Financial Crises: Aggregate Drivers. *Notes:* Global banks' net worth and EMs' systemic endowment were proxied, respectively, by the stock price of publicly traded US banks (XLF index) and by the average GDP in a sample of EMs (detailed in Supplementary Material SB2). *Data.* Objects in the figure (dashed 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 lines) refer to the dynamic response of global banks' net worth and EMs' systemic endowment to a sequence of shocks $\{\epsilon_{wt}, \epsilon_{EMt}\}$ that target the data objects during 2007–2011. 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. Calibration of the model is detailed in Section 4.1.



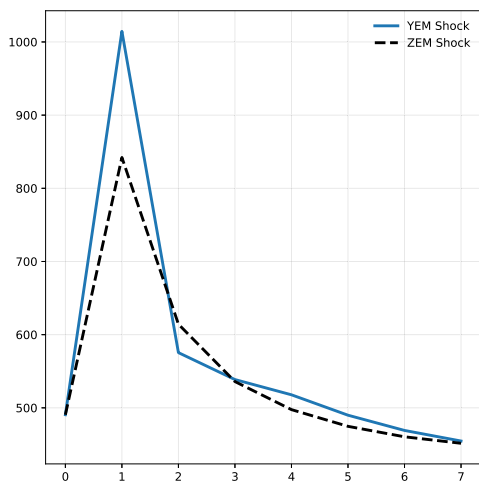
(A) Low Exposure, Ergodic Dispersion



(B) Low Exposure, High Dispersion



(C) High Exposure, Ergodic Dispersion



(D) High Exposure, High Dispersion

FIGURE SB3.—Amplification Sorted by Intermediaries’ Exposure to EMs and the Dispersion of EM Debt. *Notes:* These figures show the dynamics of spreads (in bps) following a 2-s.d. shock to the systemic (solid line) and idiosyncratic (dashed line) endowment. In the first row, global banks’ exposure to EMs is 10%; in the second row, banks’ exposure is 35%. In the first column, the initial distribution of EM debt is the ergodic one; in the second column, the initial distribution has twice the dispersion.

SB4. *Alternative Calibration Strategies*

This section describes alternative calibration strategies and extensions of the baseline model. We consider five model extensions: one that targets a lower elasticity (*Alternative Elasticity*); one that allows for different stochastic processes for idiosyncratic and aggregate EM endowments (*Measured Income Process*); one that calibrates financial intermediaries to only asset managers (*Asset Managers*); one with a state-contingent cost of external

TABLE SBI
ROBUSTNESS: FIXED PARAMETERS.

	Constant									State-Contingent	
	β_{EM}	d_0	d_1	σ	μ_{EM}	σ_{DM}	κ	\bar{n}	$\rho_{DM,EM}$	ϕ	β_{DM}
Baseline Model	0.90	0.03	14.0	0.71	2.02	0.07	3.50	0.46	0.45	2.50	0.98
Robustness											
i. Alternative Elasticity	0.90	0.03	14.0	0.71	2.06	0.07	4.00	0.70	0.45	0.70	0.98
ii. Measured Income Process*	0.92	0.06	14.0	0.71	1.95	0.07	3.40	0.35	0.45	3.50	0.98
iii. Asset Managers	0.90	0.03	14.0	0.80	1.95	0.25	0.00	0.80	0.47	0.90	0.98
iv. High Leverage	0.90	0.03	14.0	0.7	2.06	0.04	7.00	0.29	0.50	3.00	0.98
v. Time-varying ϕ	0.90	0.03	14.0	0.71	2.14	0.06	3.50	0.37	0.50	$\phi_1 = 3.00$ $\phi_2 = 0.50$	0.98
vi. Time-varying β_{DM}	0.90	0.03	14.0	0.71	2.05	0.07	3.50	0.46	0.45	2.50	$\beta_1 = 0.98$ $\beta_2 = -0.20$

Note: This table describes the values parameters take in each robustness exercise. Parameters are categorized between those that are always constant vs those that are state-contingent in some exercises. Alternative elasticity refers to the case in which we target $\eta_{EM,N} = 0.022$; Measured Income Process is the case in which the systemic and idiosyncratic components of endowment are calibrated as in the data; Asset Managers refers to the case with $\kappa = 0$; High Leverage refers to the case with $\kappa = 7$; Time-varying ϕ is for a state-contingent $\phi(\omega)$; Time-varying β_{DM} is the scenario with state-contingent risk-free rate $r_f(\omega)$. * Parameters for measured EM income process are $\rho_z = 0.82$, $\sigma_z = 0.025$, $\rho_{EM} = 0.70$, $\sigma_{EM} = 0.016$.

finance (*Cost of External Finance*); and one that introduces global liquidity policies with a state-contingent funding rate for banks (*Liquidity Policies*).

SB4.1. *Alternative Elasticity*

This extension consists of an alternative calibration strategy that targets an elasticity $\eta_{EM,N} = -0.022$ while keeping all other targets unchanged. This alternative elasticity is estimated with contemporaneous regressions (see Panel B of Table II). Row (i) of Supplementary Material Table **SBI** shows the new set of calibrated parameters. The remaining parameters are set to the same value as in the baseline calibration. Row (i) of Supplementary Material Table **SBII** reports the targeted moments. Appendix Table CIV shows that it is still the case that global banks play an important role during systemic debt crises by transmitting DM shocks rather than amplifying EM-origin shocks. In addition, Table VI shows that the contribution of the intermediation premium to total spreads is lower under this alternative calibration, but still quantitatively important.

SB4.2. *Measured Income Process*

This model extension allows for different stochastic processes for idiosyncratic and aggregate EM endowments.⁸ We measure the systemic EM endowment as 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. The calibrated parameters and targeted moments are reported in row (ii) of Supplementary Material Tables **SBI** and **SBII**, respectively. In Table VI and Appendix Table CIV, we show that the key quantitative insights of the paper regarding the role of global banks still hold.

⁸In the baseline calibration, we restricted these to follow the same stochastic process.

TABLE SBII
ROBUSTNESS: TARGETED MOMENTS.

Panel A: Benchmark Moments									
	$\mathbb{E}[D_i/Y_i]$	$\mathbb{P}[DF_i]$	$\mathbb{E}[SP_i]$	$\sigma(SP_i)$	$\text{corr}(SP_i, Y_i)$	$\sigma(\log V(N))$	$\text{corr}(\log V(N), \log Y_{EM})$	$\eta_{EM,N}$	$\mathbb{E}[\frac{d_{EM}+d_{DM}}{NF}]$
Data	15.0%	1.5%	410 bp	173 bp	-31%	0.28	40%	0.056	3.8
Baseline Model	14.4%	1.7%	416 bp	152 bp	-84%	0.24	44%	0.059	3.7
Robustness									
i. Alternative Elasticity	15.6%	1.7%	314 bp	128 bp	-86%	0.33	43%	0.026	3.4
ii. Measured Income Process	13.8%	1.3%	521 bp	192 bp	-75%	0.23	38%	0.071	3.6
iii. Asset Managers	13.7%	1.4%	470 bp	163 bp	-81%	0.24	42%	0.053	1.0
iv. High Leverage	14.7%	1.5%	378 bp	141 bp	-85%	0.23	46%	0.056	6.4
v. Time-varying ϕ	13.1%	1.5%	442 bp	141 bp	-84%	0.23	46%	0.064	3.7
vi. Time-varying β_{DM}	14.2%	1.5%	426 bp	196 bp	-72%	0.25	41%	0.05	3.4
Panel B: Extended Model Moments									
	skew(SP)		$\mathbb{E}[RF]$		cov(ln(V(N)), RF)				
Data	0.64		2.0%		0.18				
v. Time-varying ϕ	0.74		2.0%		0.2				
vi. Time-varying β_{DM}									

Note: This table shows the set of targeted moments under each robustness exercise. Panel A shows the set of moments shared with the baseline model and panel B shows an extended set of moments associated with state-contingent parameters. Alternative elasticity refers to the case in which we target $\eta_{EM,N} = 0.022$; Measured Income Process is the case in which the systemic and idiosyncratic components of endowment are calibrated as in the data; Asset Managers refers to the case with $\kappa = 0$; High Leverage refers to the case with $\kappa = 7$; Time-varying ϕ is for a state-contingent $\phi(\omega)$; Time-varying β_{DM} is the scenario with state-contingent risk-free rate $r_f(\omega)$.

SB4.3. *Asset Managers and High Leverage*

We consider two alternative calibrations involving changes in the κ parameter. The first exercise is aimed at capturing the case in which asset managers (nonlevered institutions) are the only type of global financial intermediaries in the economy. To this end, we recalibrate the model for the case when $\kappa = 0$. It is worth highlighting the fact that in this case, recursive problem (18) corresponds to a consolidated problem that maximizes the joint value of the owners' equity in the asset-management firm and the owners of the assets under management (i.e., its customers, who are assumed to be members of the DM household). In this case, the cost of raising external funds refers to either the cost of raising new external equity or the cost of expanding the customer base. This formulation abstracts from frictions between managers and customers, which are beyond the scope of the paper.

The calibrated parameters and targeted moments are reported in row (iii) of Supplementary Material Tables **SBI** and **SBII**, respectively. In Table VI and Appendix Table CIV, we show that these nonlevered institutions play a role similar to that of global banks in our baseline model. This is the case because the main mechanism by which negative shocks to intermediaries' net worth increase required returns in risky assets is still in play, since intermediaries face a higher marginal cost of raising external finance.

The second exercise is to set $\kappa = 7$ (twice that of the baseline calibration), aim at obtaining a higher level of average leverage. In this case, the recursive problem of the bank is the same as in the baseline model. The calibrated parameters and targeted moments are reported in row (iv) of Supplementary Material Tables **SBI** and **SBII**, respectively. In Table VI and Appendix Table CIV, we show that the key quantitative insights of the paper regarding the role of global banks still hold.

SB4.4. *Cost of External Finance*

This model extension allows for a time-varying marginal cost of raising external finance (ϕ_t). It is intended to capture the notion that it can be less costly for intermediaries to raise external funding during tranquil times. We parameterize the marginal cost of raising equity as $\phi(\omega) = \phi_1 \omega^{-\phi_2}$, with $\phi_1 > 0$, $\phi_2 > 0$.⁹ The calibrated parameters and targeted moments are reported in row (v) of Supplementary Material Tables **SBI** and **SBII**, respectively. We set $\phi_1 = 3$ and $\phi_2 = 0.5$ to match the EM elasticity $\eta_{EM,N} = -0.056$ and the skewness of EM spreads of 0.64, as observed in the data. Appendix Table CIV shows that it is still the case that the majority of the rise in spreads during the Lehman episode, as well as a significant fraction of the variation in consumption, can be explained by the transmission of DM shocks through global banks.

SB4.5. *Liquidity Policies*

The last model extension is to introduce global liquidity policies that cause the risk-free funding rate for banks to vary with the state. We introduce these policies by allowing the discount factor of DM households, which in equilibrium determines the deposit rate, to vary with the aggregate DM exogenous state. We parameterize the risk-free rate as $R_d^{-1}(\omega) = \beta_{DM}(\omega) = \beta_1 \omega^{\beta_2}$.¹⁰ The calibrated parameters and targeted moments are re-

⁹For numerical stability, we restrict ϕ to take values within the interval $[0.4, 5.0]$.

¹⁰For numerical stability, we restrict r_f to take values within the interval $[1.005, 1.04]$.

ported in row (vi) of Supplementary Material Tables **SBI** and **SBII**, respectively. We keep the baseline parameters and choose $\beta_1 = 0.98$ and $\beta_2 = -0.2$ to match the data moments of an average risk-free rate of 2% and a covariance of the risk-free rate and the log of the market value of intermediaries' net worth of 0.18. In Appendix Figure C4, we show that in the model with liquidity provision, the effect of the ω shock on EM bond yields and EM aggregate consumption is attenuated by roughly one-half when compared with the baseline economy. This is because funding rates decrease in response to the shock; this allows intermediaries to access funding at cheaper rates and mitigate the impact on their demand for risky assets.

SB5. *The Role of Global Banks' Equity Issuance Cost, ϕ*

Supplementary Material Table **SBIII** shows the impact of the marginal cost of equity issuance, ϕ , on the composition of the EM-spread risk premium—defined as the sum of intermediation premium and pure risk components of EM spreads. 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 and the second panel its volatility. The main takeaway is 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 to total spreads, for both the average and the standard deviation.

TABLE SBIII
EQUITY ISSUANCE COSTS AND UNCONDITIONAL DECOMPOSITION OF EM-BOND SPREADS.

	Baseline	Equity Cost			
		$\phi = 0.0$	$\phi = 0.9$	$\phi = 4.0$	$\phi = 8.0$
<i>(A) Average</i>					
Total Spread	416 bp	285 bp	396 bp	417 bp	422 bp
Default Premium	239 bp	285 bp	258 bp	230 bp	229 bp
Risk Premium	177 bp	0 bp	139 bp	186 bp	193 bp
Contribution Risk Premium	42.5%	0.0%	35.0%	44.7%	45.8%
<i>(B) Standard Deviation</i>					
Total Spread	152 bp	139 bp	137 bp	151 bp	152 bp
Default Premium	116 bp	139 bp	123 bp	112 bp	111 bp
Risk Premium	70 bp	0 bp	21 bp	75 bp	79 bp
Contribution Risk Premium	46.1%	0.0%	15.3%	49.7%	52.0%

Note: 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, $\hat{q}_{EMt}^l = \mathbb{E}_t[\beta_{DM} \iota_{it+1}(1 + \xi \hat{q}_{EMt+1}^l)]$, 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 $\{\hat{q}_{EMt}^l\}_{t=0}^{\infty}$. 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.

SB6. Cross-Sectional Asset Pricing

This Appendix provides details on the empirical exercises that assess the market value of net worth of financial intermediaries as a risk factor in pricing the cross-sectional returns on EMs in the model. We start by describing the theoretical setup and then discuss our implementation of the exercises in the observed and model-simulated data.

In the model, the stochastic discount factor (SDF) that prices EM debt is a nonlinear function of the model's state variables. In this exercise, we consider a linearized factor version of the SDF that takes the form of

$$m_{t+1} = 1 - b(f_{t+1} - \mu), \quad (59)$$

where f_t is the factor vector (which can be multidimensional), μ is its mean, and b is the factor loading. In most of the exercises, we consider a single factor given by the market value of global banks' net worth. As we will see, this factor conveys the relevant information on price securities. The linear-factor model implies that the excess expected returns of any portfolio j are given by

$$E[\tilde{r}^{ej}] = \lambda'_f \beta_{jf}, \quad (60)$$

where \tilde{r}^{ej} is the log excess return, $\lambda_f = \Sigma_{ff} b$, with Σ_{ff} being the variance-covariance matrix of the factors, and β_{jf} is the exposure of each portfolio j to the risk factor f .

The objective of our exercise is to assess how well approximated are excess expected returns under (60). We use a two-stage cross-sectional regression approach (see [Cochrane \(2005\)](#), Chapter 12) to estimate portfolios' exposure to the risk factor, the price of risk, and the cross-sectional predicted returns. In the first stage, we use the time series of the factor and the portfolio returns to obtain estimates of the exposures $\beta_{j,f}$ by estimating

$$r_{jt}^e = c_j + \beta_{jf} f_t + \epsilon_{jt}. \quad (61)$$

In the second stage, we estimate the price of risk λ_f from the cross-sectional regression

$$\bar{r}_j^e = \beta'_{jf} \lambda_f + u_j, \quad (62)$$

where \bar{r}_j^e is the average return (across time) of portfolio j . We then use the estimated price of risk to predict cross-sectional returns and compare them with the actual values.

Implementation With Observed Data. We first compute this estimation exercise on the observed data. We consider the six sovereign bond portfolios analyzed by [Borri and Verdelhan \(2011\)](#), which vary in the degree of default risk and comovement with market returns. Panels (A) and (B) of Supplementary Material Table [SBIV](#) report summary statistics of the realized returns of these bond portfolios at monthly and annual frequencies, respectively. We measure the factor as the monthly variation in the stock price of publicly traded US banks, tracked by the XLF index. Panel (A) of Supplementary Material Figure [SB4](#) shows that the linear-factor model correctly predicts the cross-section of observed expected returns for the six bond portfolios.

Implementation With Model-Simulated Data. To implement this approach in our model, we first construct six EM portfolios similar to those in [Borri and Verdelhan \(2011\)](#). Portfolios are based on (i) the covariance of EM returns with the log-change in the market value of net worth and (ii) the default probability as measured by EM spreads. Data are

TABLE SBIV
BOND PORTFOLIOS: SUMMARY STATISTICS.

β_j	Low			High		
	Low	Medium	High	Low	Medium	High
Default Prob.	1	2	3	4	5	6
Portfolios	1	2	3	4	5	6
Panel A. Data (Monthly Frequency)						
Mean	2.5%	4.6%	7.4%	7.4%	10.7%	14.7%
Std. Dev.	32.0%	37.0%	55.0%	31.8%	39.8%	66.0%
Sharpe Ratio	0.08	0.12	0.13	0.23	0.27	0.22
Panel B. Data (Annual Frequency)						
Mean	2.0%	3.8%	5.7%	6.6%	9.6%	12.1%
Std. Dev.	5.9%	8.4%	18.3%	8.1%	11.7%	27.5%
Sharpe Ratio	0.34	0.45	0.31	0.82	0.81	0.44
Panel C. Model (Annual Frequency)						
Mean	2.9%	4.0%	5.6%	3.1%	4.3%	6.0%
Std. Dev.	3.8%	4.4%	5.5%	4.0%	4.6%	5.8%
Sharpe Ratio	0.75	0.89	1.01	0.77	0.93	1.03

Note: This table shows summary statistics for EM portfolio returns, in both the model and the data. In the data, portfolio returns are obtained from [Borri and Verdelhan \(2011\)](#) at monthly frequency. In the model, we construct portfolios and returns as explained in Supplementary Material SB6.

simulated data for $T = 1000$ periods and $N = 1000$ borrowing countries. The covariance is measured by computing a 5-year rolling window estimation of

$$r_{i,t}^{\text{EM}} = \alpha_i + \beta_{i,t}^{\text{EM}} f_t + \epsilon_{i,t}, \quad (63)$$

where $r_{i,t}^{\text{EM}}$ are the returns on country i during the 5-year window ending in period t , f_t is the risk factor during this window, and $\beta_{i,t}$ is the measured covariance for that country and window. Assuming a rebalancing period of 5 years, we sort countries by having low versus high $\beta_{i,t}^{\text{EM}}$. For each of these two groups, we further differentiate countries by having low, medium, or high spreads. Panel (C) of Supplementary Material Table SBIV reports summary statistics of the simulated returns of these bond portfolios. We measure the factor as the log variation in the market value of global banks' net worth in the model. Panel (B) of Supplementary Material Figure SB4 shows that the linear-factor model correctly predicts the cross-section of model-simulated expected returns for the six bond portfolios, which suggests that the market value of global banks' net worth conveys the information relevant to price EM bonds in the model. For comparison purposes, the figure also shows the goodness-of-fit of a linear-factor model in which the factors are the model's aggregate state variables. As expected, this alternative model provides almost a full accounting of the cross-sectional variation in returns.

Implementation with observed returns and the model-implied market price of risk. We consider a third exercise in which we use the model-estimated market price of risk, λ_f , together with data-estimated loadings of bond portfolios, to estimate the observed cross-sectional excess expected returns. The goodness-of-fit of this exercise, reported in Panel (A) of Supplementary Material Figure SB4, suggests that the calibrated model also prices well the observed cross-sectional sovereign risk.

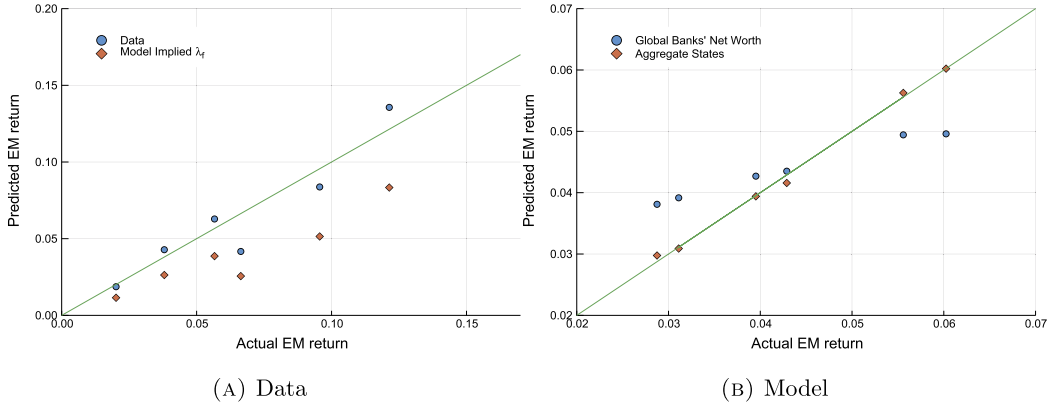


FIGURE SB4.—Cross-sectional Asset Pricing: Actual Versus Fitted. *Notes:* These figures contrast the cross-sectional returns on six EM-bond portfolio holdings (y -axis) against the realized returns (x -axis), for both model-simulated and actual data. In the data, portfolios are obtained from [Borri and Verdelhan \(2011\)](#) for the period 1995 to 2011. In the model, portfolios are constructed based on (i) the covariance of EM returns with the log-change in $V(N)$ and (ii) the default probability as measured by EM bond spreads. We consider the log-change in global banks' market value of net worth as a unique risk factor ($V(N)$ in the model and XLF in the data), and use a standard cross-sectional regression approach to compute the price of risk and the predicted returns. Panel (A) shows results in the data and compares them with the case in which we instead use the model-implied value of the price of risk, while keeping the first-stage estimated factor loadings fixed. Panel (B) shows the results of the model and compares them with the case in which we instead use aggregate states $\{Y_{EM}, \omega, A'_{DM}\}$ to price EM portfolios.

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