A Macroeconomic Framework for Quantifying Systemic Risk

Zhiguo He
University of Chicago & NBER

Arvind Krishnamurthy
Northwestern University & NBER

June 2012
Systemic Risk

- Systemic risk: risk (probability) of a state where
  - financial intermediation is disrupted
  - small fundamental shocks to financial intermediaries can have quantitatively large effects on macro economy

- Goal: Write down a non-linear macro model to assess systemic risk
  - much of the time the link between financial intermediation and macro economy is small
  - but in (crisis) states the effects are greatly amplified
Systemic Risk

- Systemic risk: risk (probability) of a state where
  - financial intermediation is disrupted
  - small fundamental shocks to financial intermediaries can have quantitatively large effects on macro economy
- Goal: Write down a non-linear macro model to assess systemic risk
  - much of the time the link between financial intermediation and macro economy is small
  - but in (crisis) states the effects are greatly amplified
- How well does the model match asymmetry (i.e. occasional effects of financial intermediation) in the data?
- How well can an intermediary shock channel explain patterns in 2007-2009?
- How likely is the economy, say unconditionally, to enter a systemic risk episode?
Innovation Relative to Much of Literature

- We study a model with occasionally binding financial constraint
- Typical models (e.g., Kiyotaki-Moore (1997),...) linearize around steady state where constraint binds.
  - Cannot talk about 1) likelihood that intermediation is disrupted (it's always disrupted...) and 2) how severely it is disrupted
- Our model solution has stochastic steady state, with fully solved equilibrium prices and policies
  - Main drawback: need to reduce state variables
  - Have to leave out some common DSGE elements
- Similar methodology to Mendoza (2010) and Brunnermeier-Sannikov (2011)
- Model elements adopted from He-Krishnamurthy (2012), with real investment and housing
Crisis: \( e^{\text{crisis}} = 0.65 \), binding capital constraint

Distress: \( e^{\text{distress}} = 4 \) so that \( \Pr(e^{\text{distress}}) = 33\% \) as in data.
Crisis: \(e_{crisis} = 0.65\), binding capital constraint

Distress: \(e_{distress} = 4\) so that \(Pr(e \leq e_{distress}) = 33\%\) as in data
Strategy

- Crises are rare. How do we quantify model?
- Even if economy is currently not in a crisis state, the anticipation of a crisis affects decisions.
  1. We match data on “distress” (33% of data) and “non-distress” periods (67% of data).
  2. We extrapolate to a crisis and ask how well the model can match patterns from 2007-2009.
  3. We compute conditional probabilities of triggering a crisis (measuring “systemic risk” probabilities).
Evidence of Non-Linearity

- **Excess bond premium** (EBP): the risk premium part of credit spread (removing default part), Gilchrist and Zakrajsek (2010). Correlates with measures of intermediary health.
- Use EBP to classify distress periods (33%) and non-distress periods (the rest)

<table>
<thead>
<tr>
<th>Distress Periods</th>
<th>NBER Recessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973Q1 - 1975Q3</td>
<td>11/73 - 3/75</td>
</tr>
<tr>
<td>1982Q2 - 1982Q4</td>
<td>7/81 - 11/82</td>
</tr>
<tr>
<td>1985Q4 - 1987Q3</td>
<td></td>
</tr>
<tr>
<td>1988Q4 - 1990Q1</td>
<td>7/90 - 3/91</td>
</tr>
<tr>
<td>1992Q4 - 1993Q2</td>
<td></td>
</tr>
<tr>
<td>2001Q2 - 2003Q1</td>
<td>3/01 - 11/01</td>
</tr>
<tr>
<td>2007Q3 - 2009Q3</td>
<td>12/07 - 6/09</td>
</tr>
</tbody>
</table>
State-Dependent Covariances (1)

- Equity = Total market value of equity of finance, insurance and real estate sectors. (works as well if only include banks + broker/dealers)
- All variables are growth, except Sharpe ratio constructed from EBP

<table>
<thead>
<tr>
<th></th>
<th>Distress</th>
<th>Non Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cov</td>
<td>Corr</td>
</tr>
<tr>
<td>Equity, Investment</td>
<td>1.31%</td>
<td>51.48</td>
</tr>
<tr>
<td>Equity, Consumption</td>
<td>0.25%</td>
<td>45.85</td>
</tr>
<tr>
<td>Equity, Sharpe</td>
<td>-6.81%</td>
<td>-35.96</td>
</tr>
<tr>
<td>Equity, Landprice</td>
<td>4.06%</td>
<td>60.65</td>
</tr>
</tbody>
</table>
State-Dependent Covariances (2)

All variables are growth, except Sharpe ratio constructed from EBP.

<table>
<thead>
<tr>
<th></th>
<th>Distress</th>
<th>Non Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NBER+2</td>
<td>Excl-Crisis</td>
</tr>
<tr>
<td>Equity, Investment</td>
<td>0.84%</td>
<td>0.37</td>
</tr>
<tr>
<td>Equity, Consumption</td>
<td>0.13%</td>
<td>0.04</td>
</tr>
<tr>
<td>Equity, Sharpe</td>
<td>-7.57%</td>
<td>-2.12</td>
</tr>
<tr>
<td>Equity, Landprice</td>
<td>4.39%</td>
<td>-0.63</td>
</tr>
</tbody>
</table>

Note: Similar numbers if only use NBER dates, but distress sample is only 20% of observations.
**VAR Evidence of Non-Linearity (3)**

VAR order: [intermediary equity, aggregate stock market, EBP, investment]. Coefficients depend on distress/non-distress state. Quarterly growth rates.

**PANEL A: DISTRESS PERIODS**

- **Equity to Equity**
- **Market to Equity**
- **EB (credit risk premium) to Equity**
- **Investment to Equity**

**PANEL B: NON DISTRESS PERIODS**

- **Equity to Equity**
- **Market to Equity**
- **EB to Equity**
- **Investment to Equity**
Road Map of the Rest of Talk

- Model, mechanism, and solution
- Calibration
  - Baseline parameters
  - Prices and policies, comparative statics
- Matching data on distress and non-distress
- Systemic crisis
  - Extrapolate to crisis state
  - Uncover fundamental shocks in the recent crisis
  - How likely are crises?
Agents and Technology

- Two classes of agents: households and bankers
  - Households own the entire economy, but subject to frictions related to bankers who control intermediaries (next slide)
- Two types of capital: productive capital $K_t$ and housing capital $H$. Fixed supply of housing $H \equiv 1$
  - Price of capital $q_t$ and price of housing $P_t$ determined in equilibrium
Agents and Technology

- Two classes of agents: households and bankers
  - Households own the entire economy, but subject to frictions related to bankers who control intermediaries (next slide)
- Two types of capital: productive capital $K_t$ and housing capital $H$. Fixed supply of housing $H \equiv 1$
  - Price of capital $q_t$ and price of housing $P_t$ determined in equilibrium
- Production $Y = AK_t$, with $A$ being constant
- Fundamental shocks: stochastic capital quality shock $dZ_t$

\[
\frac{dK_t}{K_t} = i_t dt - \delta dt + \sigma dZ_t
\]

- Investment/Capital $i_t$, quadratic adjustment cost

\[
\Phi(i_t, K_t) = i_t K_t + \frac{\kappa}{2} (i_t - \delta)^2 K_t
\]
Aggregate Balance Sheet

Loans to Capital Producers $i_t$

Intermediary Sector

- Capital $q_t K_t$
- Housing $P_t H$

Equity $E_t$

Debt $W_t - E_t$

Household Sector

Financial Wealth

$W_t = q_t K_t + P_t H$
Aggregate Balance Sheet

Loans to Capital Producers $i_t$

Intermediary Sector

Capital $q_t K_t$

Equity $E_t$

Housing $P_t H$

Debt $W_t - E_t$

Aggregate bank reputation $\mathcal{E}_t$

Financial Wealth

Household Sector

Equity

Constraint: $E_t \leq \mathcal{E}_t$

No constraint

$W_t = q_t K_t + P_t H$
Single Bank/Banker

<table>
<thead>
<tr>
<th>Capital $q_t k_t$</th>
<th>Equity $e_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing $P_t h_t$</td>
<td>Debt $d_t$</td>
</tr>
</tbody>
</table>

Portfolio share in capital: \( \alpha_t^k = \frac{q_t k_t}{e_t} \)

Portfolio share in housing: \( \alpha_t^h = \frac{P_t h_t}{e_t} \)

Borrowing (no constraint): \( d_t = q_t k_t + P_t h_t - e_t = (\alpha_t^k + \alpha_t^h - 1)e_t \)

Return on bank equity: \( d\tilde{R}_t = \alpha_t^k dR_t^k + \alpha_t^h dR_t^h - (\alpha_t^k + \alpha_t^h - 1) r_t dt \)

Banker (log preference) solves: \( \max_{\alpha_t^k, \alpha_t^h} E[d\tilde{R}_t - r_t dt] - \frac{m}{2} \text{Var}_t[d\tilde{R}_t] \)
Single Bank/Banker

<table>
<thead>
<tr>
<th>Capital  $q_t k_t$</th>
<th>Equity  $e_t$</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing  $P_t h_t$</td>
<td>Debt  $d_t$</td>
<td>- $(k, h)$ scales with $e$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- $(k, h)$ increasing in $E_t[dR - r]$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- $(k, h)$ decreasing in $Var[dR]$</td>
</tr>
</tbody>
</table>

Portfolio share in capital:  $\alpha^k_t = \frac{q_t k_t}{e_t}$

Portfolio share in housing:  $\alpha^h_t = \frac{P_t h_t}{e_t}$

Borrowing (no constraint):  $d_t = q_t k_t + P_t h_t - e_t = (\alpha^k_t + \alpha^h_t - 1)e_t$

Return on bank equity:  $d\tilde{R}_t = \alpha^k_t dR^k_t + \alpha^h_t dR^h_t - (\alpha^k_t + \alpha^h_t - 1)r_t dt$

Banker (log preference) solves:  $\max_{\alpha^k_t, \alpha^h_t} E[d\tilde{R}_t - r_t dt] - \frac{m}{2} Var_t[d\tilde{R}_t]$
**General Equilibrium (1)**

**Intermediary Sector**

<table>
<thead>
<tr>
<th>Capital $q_tK_t$</th>
<th>Equity $E_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing $p_tH$</td>
<td>Debt $W_t - E_t$</td>
</tr>
</tbody>
</table>

**Household Sector**

<table>
<thead>
<tr>
<th>Financial Wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_t = q_tK_t + p_tH$</td>
</tr>
</tbody>
</table>

**Constraint:** $E_t \leq \mathcal{E}_t$

Portfolio share in capital: $\alpha_t^k = \frac{q_tK_t}{E_t}$

Portfolio share in housing: $\alpha_t^h = \frac{P_tH}{E_t}$

- Given a particular state $(K_t, \mathcal{E}_t)$, the portfolio shares are pinned down by GE.
- Portfolio shares must also be optimally chosen by banks.

\[
\max_{\alpha_t^k, \alpha_t^h} \mathbb{E}_t[\tilde{R}_t - r_t dt] - \frac{m}{2} \text{Var}_t[\tilde{R}_t]
\]
### General Equilibrium (2)

<table>
<thead>
<tr>
<th>Intermediary Sector</th>
<th>Household Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital $q_tK_t$</td>
<td>Financial Wealth</td>
</tr>
<tr>
<td>Housing $p_tH$</td>
<td>$W_t = q_tK_t + p_tH$</td>
</tr>
<tr>
<td>Equity $E_t$</td>
<td></td>
</tr>
<tr>
<td>Debt $W_t - E_t$</td>
<td></td>
</tr>
</tbody>
</table>

**Constraint:** $E_t \leq \mathcal{E}_t$

- Portfolio share in capital: $\alpha^k_t = \frac{q_tK_t}{E_t}$
- Portfolio share in housing: $\alpha^h_t = \frac{P_t}{E_t}$

- Prices (returns) have to adjust for optimality:
  - $\mathbb{E}_t[dR^h_t - r_t dt], \mathbb{E}_t[dR^k_t - r_t dt] \Rightarrow$ equations for $\mathbb{E}_t[dP_t], \mathbb{E}_t[dq_t]$

- Rewrite to get ODEs for $P(K, \mathcal{E})$ and $q(K, \mathcal{E})$

- Scale invariance: Define $e \equiv \mathcal{E}/K$; then $P = Kp(e)$ and $q(e)$
Capital Producers and Investment

- Capital goods producers (owned by households) undertake real investment.
- Producers must sell the capital stock to intermediaries at price $q_t$.
  - Risk averse intermediaries bear aggregate fundamental shocks.
  - Real investment is affected by financial condition of intermediaries to capture “credit crunch”.
- Possible interpretations:
  - Entrepreneurs raise capital from VC/PE at the price of $q_t$.
  - Commercial banks make collateralized loans.
- Investment decision:
  $$\max_{i_t} q_t i_t K_t - \Phi(i_t, K_t) \Rightarrow i_t = \delta + \frac{q_t - 1}{\kappa}$$
Capital Constraint

- Single bank has reputation $\epsilon_t$ linked to intermediary performance (constant $m$)

\[ \frac{d\epsilon_t}{\epsilon_t} = m\tilde{R}_t. \]

- Poor past returns reduce reputation
- Households invest a maximum of $\epsilon_t$ dollars of equity capital with this banker

Note: $E_t$ is like "net worth" in many other models.
Capital Constraint

- Single bank has reputation $\epsilon_t$ linked to intermediary performance (constant $m$)

$$ \frac{d\epsilon_t}{\epsilon_t} = m\tilde{R}_t. $$

- Poor past returns reduce reputation

- Households invest a maximum of $\epsilon_t$ dollars of equity capital with this banker

- Death rate $\eta$, and entry $d\psi_t > 0$ of new bankers in extreme states (modeled later)

- $E_t$: aggregate reputation. Identical banks, aggregate dynamics of $E_t$

$$ \frac{dE_t}{E_t} = md\tilde{R}_t - \eta dt + d\psi_t $$
Capital Constraint

- Single bank has reputation $\epsilon_t$ linked to intermediary performance (constant $m$)
  \[
  \frac{d\epsilon_t}{\epsilon_t} = m\tilde{R}_t.
  \]
  - Poor past returns reduce reputation
- Households invest a maximum of $\epsilon_t$ dollars of equity capital with this banker
- Death rate $\eta$, and entry $d\psi_t > 0$ of new bankers in extreme states (modeled later)
- $\mathcal{E}_t$: aggregate reputation. Identical banks, aggregate dynamics of $\mathcal{E}_t$
  \[
  \frac{d\mathcal{E}_t}{\mathcal{E}_t} = md\tilde{R}_t - \eta dt + d\psi_t
  \]
  - Note: $\mathcal{E}_t$ is like “net worth" in many other models.
Households’ Problem (1)

- Choose consumption $c_y^t$ and housing $c_h^t$ to maximize

$$\mathbb{E} \left[ \int_0^\infty e^{-\rho t} \left( (1 - \phi) \ln c_y^t + \phi \ln c_h^t \right) dt \right]$$

- Equilibrium rental price $D_t$ (housing asset dividend), FOC

$$\frac{c_h^t D_t}{\phi} = \frac{c_y^t}{1 - \phi}.$$ In equilibrium ($C_h^t = H = 1$)

$$D_t = \frac{\phi}{1 - \phi} C_y^t$$

- $\phi$: expenditure share in housing, or the relative size of housing sector

- Households free to trade short-term debt.

- Interest rate $r_t = \rho + \mathbb{E}_t \left[ \frac{dC_y^t}{C_y^t} \right] - \text{Var}_t \left[ \frac{dC_y^t}{C_y^t} \right]$
Households’ Problem (2)

- Representative household enters time $t$ with financial wealth $W_t$
- The household splits wealth: $(1 - \lambda) W_t$ to “equity households,” $\lambda W_t$ to “bond households”
  - Equity households invest their portion of wealth as equity of intermediaries, subject to capital frictions
  - Bond households invest in riskless bonds
- Once returns are realized, both members pool their wealth again (as in Lucas 1990)
- The only role of bond households (i.e. parameter $\lambda$) is to introduce intermediary’s leverage in normal time
Debt/Equity Ratio

Loans to Capital Producers $i_t$

Intermediary Sector

Capital $q_t K_t$

Equity $E_t$

Constraint: $E_t \leq \mathcal{E}_t$

Housing $P_t H$

Debt $W_t - E_t$

No constraint

Aggregate bank reputation $\mathcal{E}_t$

Household Sector

Financial Wealth

$W_t = q_t K_t + p_t H$

$(1 - \lambda) W_t$

$\lambda W_t$

Constraint:

$E_t \leq \mathcal{E}_t$
Equity Capital Constraint

- Unconstrained capital structure: $\lambda W_t$ of Debt, $(1 - \lambda) W_t$ of Equity.
- Intermediary equity capital $E_t$ is given by
  \[
  E_t = \min[E_t, (1 - \lambda) W_t]
  \]

- How can capital constraint come to bind, beginning in a state where $E_t > (1 - \lambda) W_t$?

- Suppose a $-10\%$ shock to real estate and price of capital, so that $W_t \downarrow 10\%$ (Household wealth = aggregate wealth)

- Reputation follows $\frac{dE_t}{E_t} = md\tilde{R}_t + \ldots$ Two forces make $E_t \downarrow$ more than 10%:
  - Equity is levered claim on assets: Return on equity = $d\tilde{R}_t < -10\%$
  - $m > 1$ in our calibration.
Boundary Conditions

- When $e = \infty$, $E_t > (1 - \lambda) W_t$ frictionless economy
  - We solve for $p(\infty), q(\infty)$ analytically
- As $e \to 0$, intermediaries’ portfolio volatility, i.e. Sharpe ratio, rises
- New bankers enter if $e = e$ (Sharpe ratio hits $\gamma$, exogenous constant)
  - Entry increases aggregate $E$ but requires physical capital $K$ at conversion rate of $\beta$
  - $e$ is a reflecting boundary
- Boundary conditions at the entry point $e$

\[ q'(e) = 0, \quad p'(e) = \frac{p(e) \beta}{1 + e \beta}, \quad \text{and} \quad \text{Sharpe Ratio}(e) = \gamma \]
## Calibration: Baseline Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Choice</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Intermediation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m$ Performance sensitivity</td>
<td>2.5</td>
<td>Average Sharpe ratio (38%)</td>
</tr>
<tr>
<td>$\lambda$ Debt ratio</td>
<td>0.5</td>
<td>Average intermediary leverage</td>
</tr>
<tr>
<td>$\eta$ Banker exit rate</td>
<td>13%</td>
<td>Good model dynamics</td>
</tr>
<tr>
<td>$\gamma$ Entry trigger</td>
<td>5.5</td>
<td>Highest Sharpe ratio</td>
</tr>
<tr>
<td>$\beta$ Entry cost</td>
<td>2.35</td>
<td>Land price volatility</td>
</tr>
<tr>
<td>Panel B: Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma$ Capital quality shock</td>
<td>5%</td>
<td>Investment and Consumption volatilities</td>
</tr>
<tr>
<td>$\delta$ Depreciation rate</td>
<td>10%</td>
<td>Literature</td>
</tr>
<tr>
<td>$\kappa$ Adjustment cost</td>
<td>2</td>
<td>Literature</td>
</tr>
<tr>
<td>$A$ Productivity</td>
<td>0.14</td>
<td>Investment-to-capital ratio</td>
</tr>
<tr>
<td>Panel C: Others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$ Time discount rate</td>
<td>2%</td>
<td>Literature</td>
</tr>
<tr>
<td>$\phi$ Housing share</td>
<td>0.5</td>
<td>Housing-to-wealth ratio</td>
</tr>
</tbody>
</table>
Equilibrium Prices and Policies (1)

- $e_{\text{crisis}} = 0.65$: binding capital constraint
- $e_{\text{distress}} = 4$ so that $\Pr(e \leq e_{\text{distress}}) = 33\%$ as in data
Equilibrium Prices and Policies (2)

- \( e_{\text{crisis}} = 0.65 \): binding capital constraint
- \( e_{\text{distress}} = 4 \) so that \( \Pr(e \leq e_{\text{distress}}) = 33\% \) as in data

![Graphs showing various economic indicators and distributions](image_url)
## Matching State-Dependent Covariances: Baseline

<table>
<thead>
<tr>
<th></th>
<th>Distress</th>
<th></th>
<th>Non Distress</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Baseline</td>
<td>Data</td>
<td>Baseline</td>
</tr>
<tr>
<td>$vol (Eq)$</td>
<td>31.48%</td>
<td>26.01</td>
<td>17.54</td>
<td>6.77</td>
</tr>
<tr>
<td>$vol (I)$</td>
<td>8.05%</td>
<td>5.73</td>
<td>6.61</td>
<td>5.39</td>
</tr>
<tr>
<td>$vol (C)$</td>
<td>1.71%</td>
<td>3.29</td>
<td>1.28</td>
<td>3.94</td>
</tr>
<tr>
<td>$vol (LP)$</td>
<td>21.26%</td>
<td>22.87</td>
<td>9.79</td>
<td>9.38</td>
</tr>
<tr>
<td>$vol (EB)$</td>
<td>60.14%</td>
<td>49.96</td>
<td>12.72</td>
<td>6.32</td>
</tr>
<tr>
<td>$cov (Eq, I)$</td>
<td>1.31%</td>
<td>0.80</td>
<td>0.07</td>
<td>0.36</td>
</tr>
<tr>
<td>$cov (Eq, C)$</td>
<td>0.25%</td>
<td>0.34</td>
<td>0.03</td>
<td>0.26</td>
</tr>
<tr>
<td>$cov (Eq, LP)$</td>
<td>4.06%</td>
<td>4.56</td>
<td>0.12</td>
<td>0.63</td>
</tr>
<tr>
<td>$cov (Eq, EB)$</td>
<td>-6.81%</td>
<td>-6.69</td>
<td>-0.14</td>
<td>-0.09</td>
</tr>
</tbody>
</table>
Matching State-Dependent Covariances: lower $\sigma$

<table>
<thead>
<tr>
<th></th>
<th>Distress</th>
<th>Non Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Baseline</td>
</tr>
<tr>
<td>$vol\ (Eq)$</td>
<td>31.48%</td>
<td>26.01</td>
</tr>
<tr>
<td>$vol\ (I)$</td>
<td>8.05%</td>
<td>5.73</td>
</tr>
<tr>
<td>$vol\ (C)$</td>
<td>1.71%</td>
<td>3.29</td>
</tr>
<tr>
<td>$vol\ (LP)$</td>
<td>21.24%</td>
<td>21.26</td>
</tr>
<tr>
<td>$vol\ (EB)$</td>
<td>60.14%</td>
<td>48.96</td>
</tr>
<tr>
<td>$cov\ (Eq, I)$</td>
<td>1.31%</td>
<td>0.81</td>
</tr>
<tr>
<td>$cov\ (Eq, C)$</td>
<td>0.25%</td>
<td>0.35</td>
</tr>
<tr>
<td>$cov\ (Eq, LP)$</td>
<td>4.06%</td>
<td>4.56</td>
</tr>
<tr>
<td>$cov\ (Eq, EB)$</td>
<td>-6.81%</td>
<td>-6.69</td>
</tr>
</tbody>
</table>
# Matching State-Dependent Covariances: No Housing

<table>
<thead>
<tr>
<th></th>
<th>Distress</th>
<th>Non Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Baseline</td>
</tr>
<tr>
<td>$vol (Eq)$</td>
<td>31.48%</td>
<td>26.09</td>
</tr>
<tr>
<td>$vol (I)$</td>
<td>8.05%</td>
<td>5.73</td>
</tr>
<tr>
<td>$vol (C)$</td>
<td>1.71%</td>
<td>3.29</td>
</tr>
<tr>
<td>$vol (EB)$</td>
<td>60.14%</td>
<td>48.96</td>
</tr>
<tr>
<td>$cov (Eq, I)$</td>
<td>1.31%</td>
<td>0.81</td>
</tr>
<tr>
<td>$cov (Eq, C)$</td>
<td>0.25%</td>
<td>0.35</td>
</tr>
<tr>
<td>$cov (Eq, LP)$</td>
<td>4.06%</td>
<td>4.56</td>
</tr>
<tr>
<td>$cov (Eq, EB)$</td>
<td>-6.81%</td>
<td>-6.69</td>
</tr>
</tbody>
</table>
Uncovering Shocks in the Recent Crisis

Data

Model

Based on realized equity return we uncover fundamental shocks to the economy. Capital constraint binds after 08QII—systemic crisis. In the model (data), land price falls by 71% (55%).
Uncovering Shocks in the Recent Crisis

Based on realized equity return we uncover fundamental shocks to $K$

\[
\begin{array}{cccccccccccc}
07\text{QIII} & 07\text{QIV} & 08\text{QI} & 08\text{QII} & 08\text{QIII} & 08\text{QIV} & 09\text{QI} & 09\text{QII} & 09\text{QIII} & 09\text{QIV} \\
-3.77\% & -7.24 & -6.62 & -2.85 & -0.48 & -3.10 & -2.32 & -1.15 & -0.04 & -0.77 \\
\end{array}
\]

Total -25%. Capital constraint binds after 08QII—systemic crisis

- In the model (data), land price fall by 71% (55%)
**Probability of Crisis**

- 2007Q2, $\text{Prob}(\text{crisis occurs in the next 2 years}) = 0.09\%$, $\text{Prob}(5 \text{ years}) = 2.62\%$, $\text{Prob}(10 \text{ years}) = 10.05\%$

Note: Probabilities are low, which suggests improved capital buffers would have limited effects.
**Probability of Crisis**

- 2007Q2, \( \text{Prob(crisis occurs in the next 2 years)} = 0.09\% \), \( \text{Prob(5 years)} = 2.62\% \), \( \text{Prob (10 years)} = 10.05\% \)
- Conditional probability of hitting crisis (left) or distress (right)

Note: Probabilities are low, which suggests improved capital buffers would have limited effects.
VIX and Systemic Risk

- Volatility in our model rises most sharply when the constraint binds.
- Coincident indicator and no predictive content.
- What might work better? A VIX spread: Long-maturity VIX minus short-maturity VIX.
- Other indicators...
Conclusion

- We develop a fully stochastic model of systemic crisis, with two major frictions:
  - Equity capital constraint on intermediary sector
  - Intermediaries have substantial holdings in real assets (physical capital or housing)
- We find that the model
  - not only qualitatively delivers the nonlinearity observed in the data
  - but also quantitatively matches the differential comovements in distress and non-distress periods
- Recent 07/08 crisis requires a cumulative negative shock around -25%
- Things we are working on: more on model-based measure of systemic risk