A Macroeconomic Framework for Quantifying Systemic Risk

Zhiguo He, University of Chicago and NBER
Arvind Krishnamurthy, Stanford University and NBER

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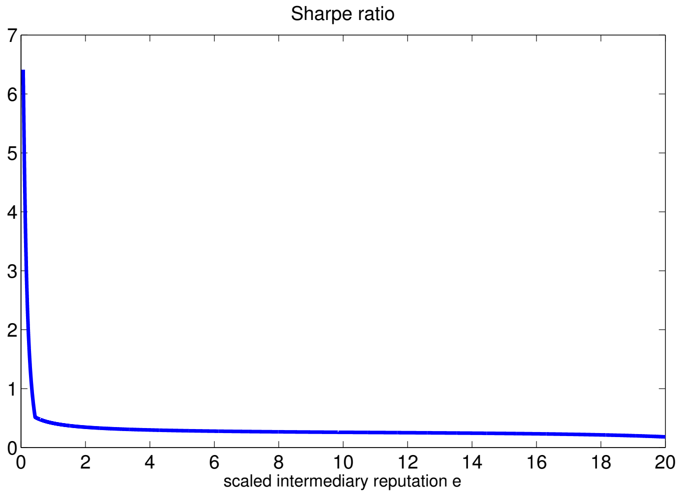
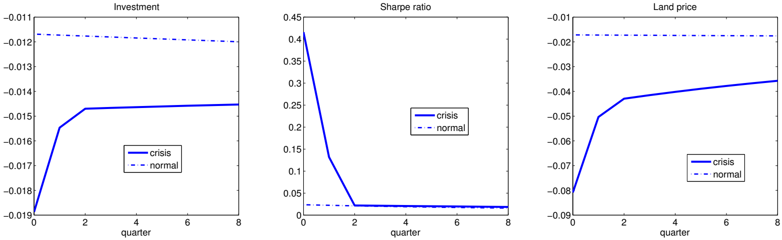
Financial Crisis in the Model

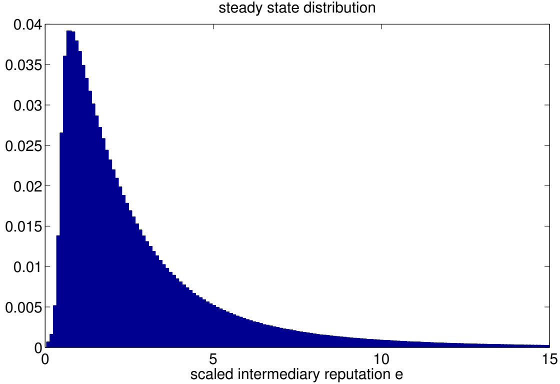


Note: Capital constraint binds for $e < 0.435$

Non-linearity: State-dependent Impulse Response: -1% Shock



Global Solution: Steady State Distribution



Model-based stress test

- Pick initial condition to match 2007Q2 asset prices
- Probability of crisis over horizon:
  - 1 year: 0.32%
  - 2 year: 3.57%
  - 5 year: 17.30 %
- Initial condition + rational forward looking agents = can't see around corners!

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- Stress test:
  - Add $2 trillion of shadow banking liabilities, with close to 0% capital.
  - This information was not in 2007Q2 asset prices
- Probability of crisis over horizon:
  - 1 year: 6.73%
  - 2 year: 23.45%
  - 5 year: 57.95 %

Outline of Presentation

1. Nonlinear macro model of a financial crisis
    - Recent work on financial intermediaries: He-Krishnamurthy, Brunnermeier-Sannikov, Rampini-Viswanathan, Adrian-Boyarchenko, Gertler-Kiyotaki
    - Our approach: occasionally binding constraint; global solution method (similar to Brunnermeier-Sannikov, Adrian-Boyarchenko)

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    - Our approach: occasionally binding constraint; global solution method (similar to Brunnermeier-Sannikov, Adrian-Boyarchenko)
2. Calibration and results
3. Quantify systemic risk and stress test

Model

- Two classes of agents: households and bankers
  - Households:

$$\mathbb{E}\left[\int_0^\infty e^{-\rho t}\frac{1}{1-\gamma}C_t^{1-\gamma}dt\right], \qquad C_t = \left(c_t^y\right)^{1-\phi}\left(c_t^h\right)^{\phi}$$

- 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

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- Fundamental shocks: stochastic capital quality shock dZ_t. TFP shocks

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

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- Investment/Capital i_t, quadratic adjustment cost

$$\Phi(i_t, K_t) = i_t K_t + \frac{\kappa}{2}\left(i_t - \delta\right)^2 K_t$$

$$\max_{i_t}\ q_t i_t K_t - \Phi(i_t, K_t) \ \Rightarrow\ i_t = \delta + \frac{q_t - 1}{\kappa}$$

Aggregate Balance Sheet

Loans to Capital Producers i_t

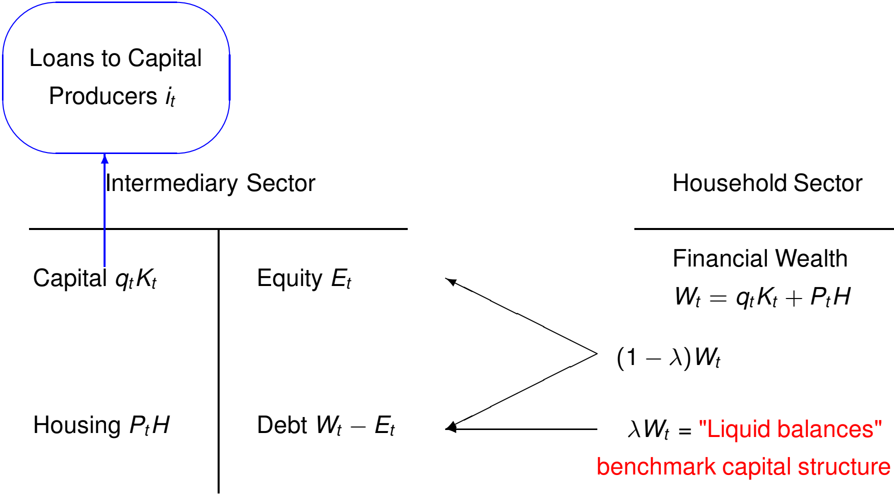
Intermediary Sector

Assets	Liabilities
Capital $q_t K_t$	Equity E_t
Housing $P_t H$	Debt $W_t - E_t$

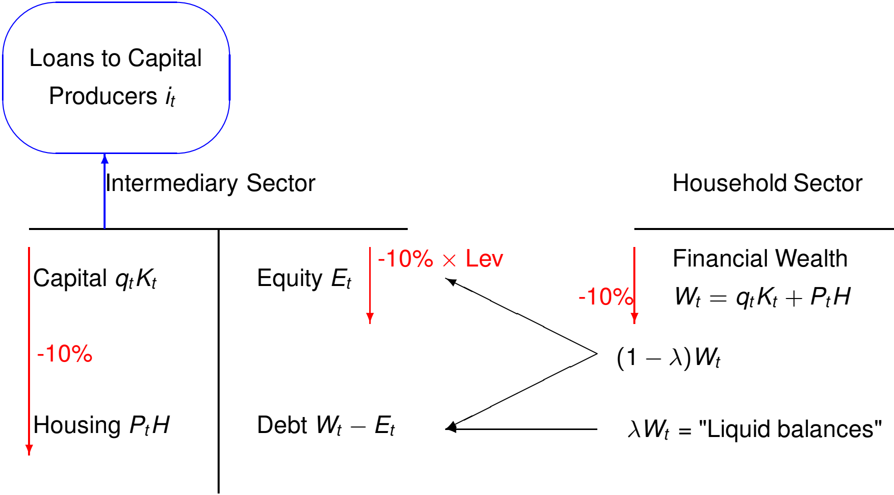
Household Sector

Financial Wealth $W_t = q_t K_t + P_t H$

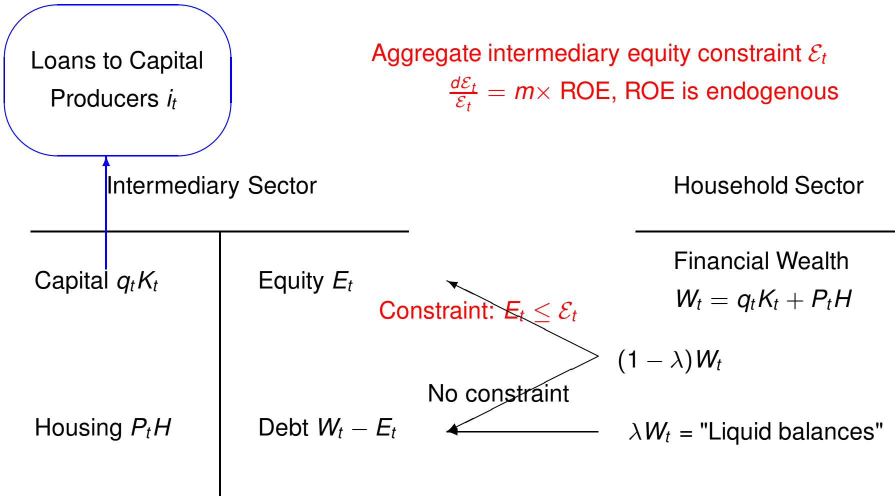
Aggregate Balance Sheet



Equity Dynamics in GE



Equity Constraint



Equity constraint: ϵ_t

- Bank can raise equity upto ϵ_t at zero cost
- Cost of raising equity more than ϵ_t is infinite.
- ϵ_t linked to intermediary performance (constant m)

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

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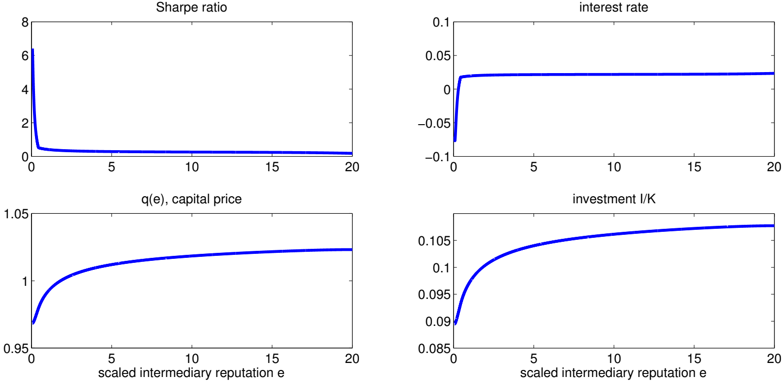
  - ϵ_t as "reputation" of the banker
  - ϵ_t as banker's "net worth" fluctuating with past returns
- Aggregate dynamics of $\mathcal{E}_t = \int \epsilon_t$

Calibration: Baseline Parameters

	Parameter	Choice	Targets (Unconditional)
Panel A: Intermediation			
m	Performance sensitivity	2	Average Sharpe ratio (model=38%)
λ	Debt ratio	0.67	Average intermediary leverage
η	Banker exit rate	13%	Prob. of crisis (model,data = 3%)
γ	Entry trigger	6.5	Highest Sharpe ratio
β	Entry cost	2.43	Average land price vol (model,data=14%)
Panel B: Technology			
σ	Capital quality shock	3%	Consumption volatility (model=1.4%)
			Note: Model investment vol = 4.5%
δ	Depreciation rate	10%	Literature
κ	Adjustment cost	3	Literature
A	Productivity	0.133	Average investment-to-capital ratio
Panel C: Others			
ρ	Time discount rate	2%	Literature
ξ	1/EIS	0.15	Interest rate volatility
ϕ	Housing share	0.5	Housing-to-wealth ratio

Results(1): State variable is $e_t = \mathcal{E}_t / K_t$



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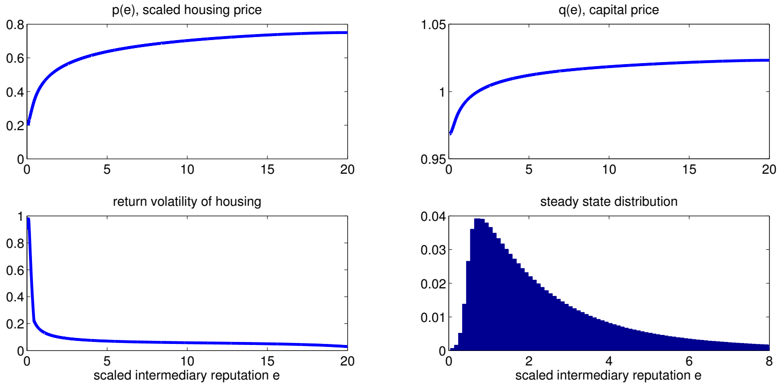
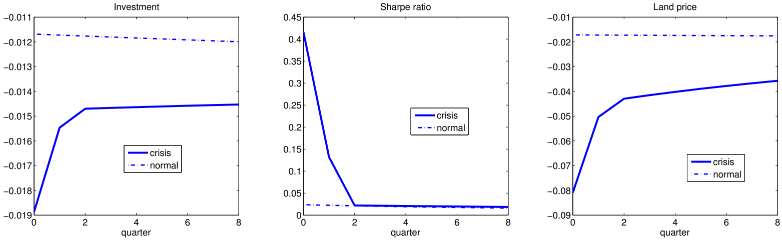
Results(2)



- Capital constraint binds for $e < 0.435$
- Without the possibility of the capital constraint, all of these lines would be flat. Model dynamics would be i.i.d., with vol=3%

State-dependent Impulse Response: -1% Shock ($= \sigma dZ_t$) ▸ VARdata



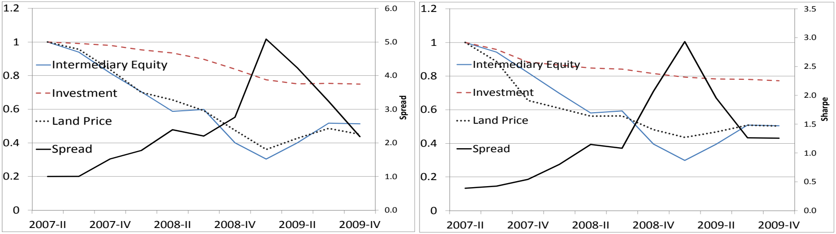
Matching the 2007-2009 Crisis

Pick initial condition for intermediary state variable (e) to match asset prices in 2007Q2

- Asset price = Gilchrist-Zakrajsek credit spread
- *Note: this spread (as with most spreads) was low in 2007Q2*
- Data from 1975 to 2010; compute histogram of spread variable
- Match percentile of spread in the data to the same percentile in model implied distribution for risk premium

- Answer: In 2007Q2, $e = 1.27$.

Matching Recent Crisis: *Data(L) and Model(R)*



- Set initial condition of $e = 1.27$ in 2007Q2.
- Then choose $(Z_{t+1} - Z_t)$ shocks to match realized intermediary equity series.

07QIII	07QIV	08QI	08QII	08QIII	08QIV	09QI	09QII	09QIII	09QIV
-2.5%	-4.2	-1.1	-1.1	-0.7	-1.6	-1.8	-1.8	-0.9	-0.9

  - Total -15.5%. Capital constraint binds after 07Q4—systemic risk state
  - In the model (data), land price falls by 50% (55%)
  - In the model (data), investment falls by 23% (25%)

Systemic Risk: What is the probability of the 2007-2009 crisis?

- What is the likelihood of the constraint binding (“systemic crisis") assuming $e = 1.27$ currently:
  - 0.32% in next 1 years
  - 3.57% in next 2 years
  - 17.30% in next 5 years

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Lessons:

- Initial condition calibrated to asset prices + rational forward looking agents = can’t see around corners!
- Even with a highly non-linear model
- Could abandon RE. Credit growth unusually high, crash likely, even though asset markets dont see it

Stress testing: Leverage test

- Financial sector aggregate leverage fixed at 3 in model
  - We measure across commercial banks, broker/dealers, hedge funds in 2007:
  - Assets = $15,703 billion; Liabilities = $10,545 billion
- Suppose a stress test uncovered leverage:
  - ABCP (SIVs): $1,189 billion; Liabilities $1,189 billion
  - Repo (MMFs and Sec Lenders): $1,020 billion; Liabilities $1,000 billion (assumed 2% haircut)
- Leverage is “hidden" in sense that agents take equilibrium functions as given based on leverage=3
  - 1 year: 6.73%
  - 2 year: 23.45%
  - 5 year: 57.95 %

Stress testing plus a model

- In current practice, work goes into estimating exposure (i.e. true leverage in example)

With a model:

1. Stress may trigger macro and asset price feedbacks, second round,... third round...
   - Model computes the fixed point
2. Model translates stress event into a probability of a systemic crisis
3. Model can help calibrate corrective actions (i.e. capital raising) based on target:
   - How much capital is needed to ensure probability of crisis < X%?
   - “Macro-VAR"

Stress testing

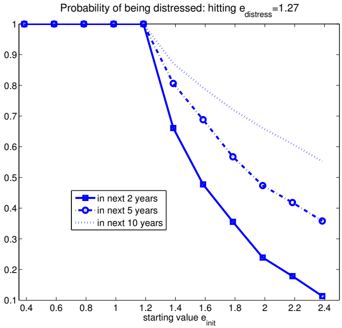
Key step: Need to map from stress scenario into underlying shock, dZ_t.

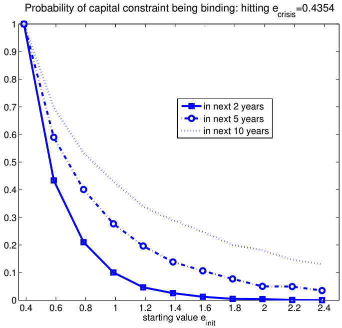
- Say stress scenario $\Rightarrow$ -30% Return on equity
- Naive partial eqbm: leverage of 3, $\sigma(Z_{t+0.25} - Z_t) = -30/3 = -10\%$.
- Feed in -10% shock into the model over one quarter.
- Result: Beginning at $e = 1.27$ in 2007Q2, economy is immediately moved into crisis region, $e < 0.435$
- our model helps in figuring out the right shock dZ_t

In US stress tests, scenario was over 6 quarters. Feed in shocks quarter-by-quarter, over 6 quarters:

Return on Equity	6 QTR Shocks	Prob(Crisis within next 2 years)
-2%	-1.16%	5.25 %
-5	-2.53%	8.90
-10	-4.69%	22.88
-15	-6.71%	48.90
-30	-8.72%	100.00

Stress testing



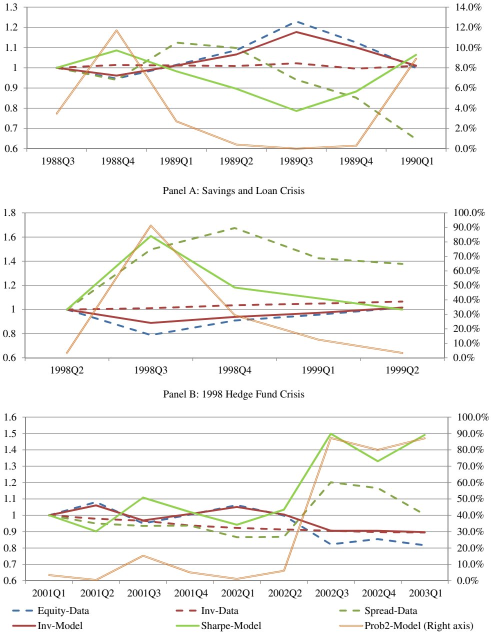


Map “stress test" into a shock to e.

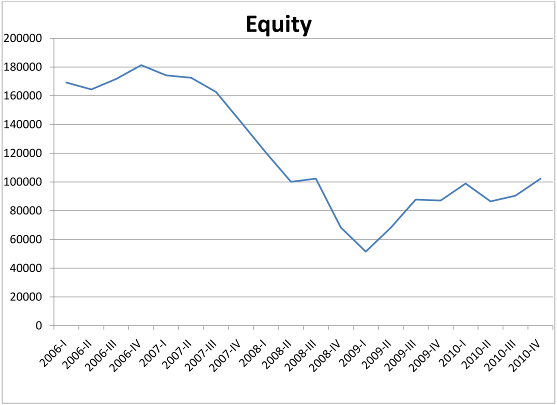
Conclusion

- We develop a fully stochastic model of a systemic crisis, with an equity capital constraint on the intermediary sector
- Is able to replicate 2007/2008 period with only intermediary capital shocks
- The model quantitatively matches the differential comovements in distress and non-distress periods
- Offers a way of mapping macro-stress tests into probability of systemic states.

Other crises



Equity series



VIX


VIX
90
80
70
60
50
40
30
20
10
0
Jan-06
Mar-06
May-06
Jul-06
Sep-06
Nov-06
Jan-07
Mar-07
May-07
Jul-07
Sep-07
Nov-07
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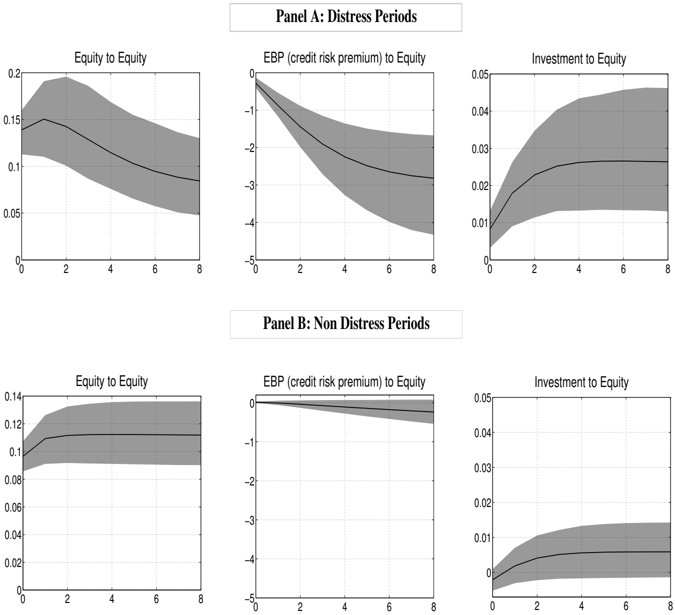
Panel A: Distress Periods
Equity to Equity
EBP (credit risk premium) to Equity
Investment to Equity
Panel B: Non Distress Periods
Equity to Equity
EBP (credit risk premium) to Equity
Investment to Equity