A Macroeconomic Framework for Quantifying Systemic Risk

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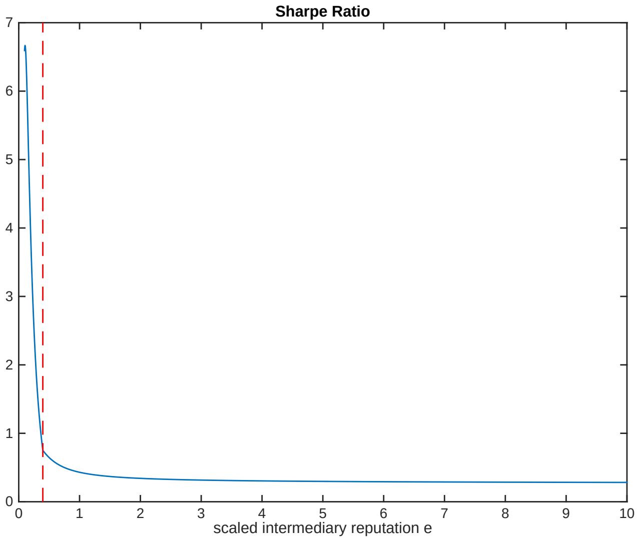
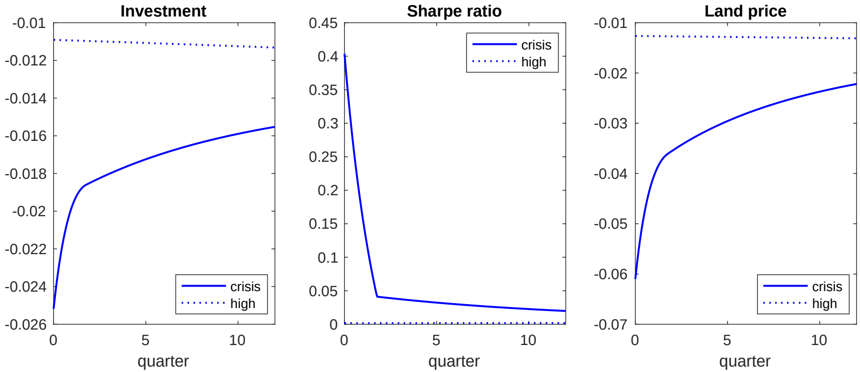
Financial Crisis in the Model

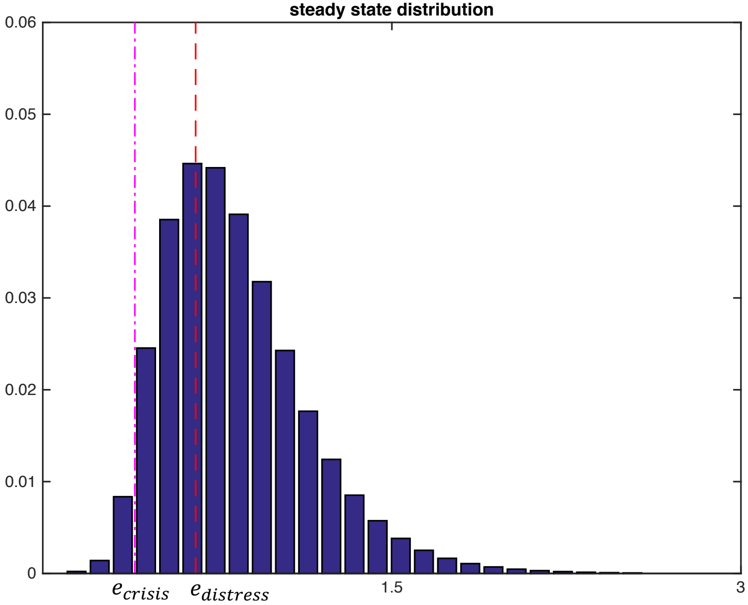


Note: Capital constraint binds for $e < 0.396$

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



Global Solution: Steady State Distribution



Model-based stress test

- Pick initial condition to roughly match 2007Q3 asset prices
- Probability of crisis over horizon:
  - 1 year: 3%
  - 2 year: 16%
  - 5 year: 44 %

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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: unanticipated shock
- Probability of crisis over horizon:
  - 1 year: 10%
  - 2 year: 30%
  - 5 year: 57%

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.

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

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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

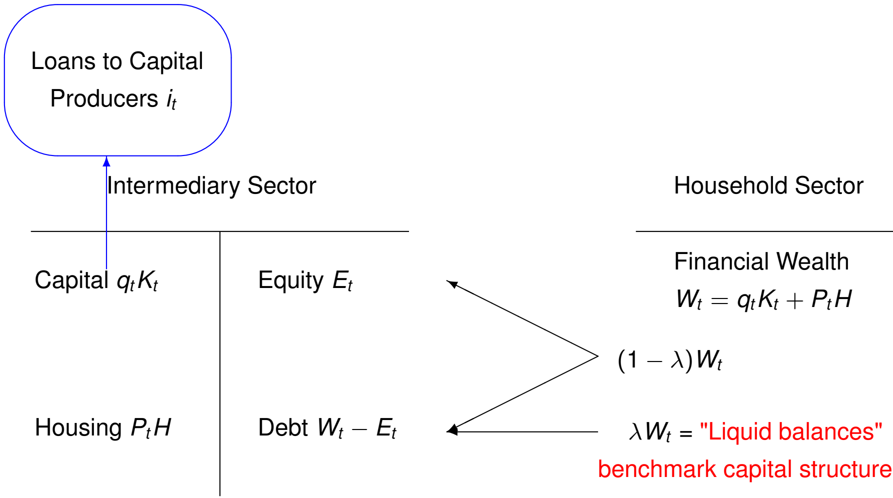
Intermediary Sector

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

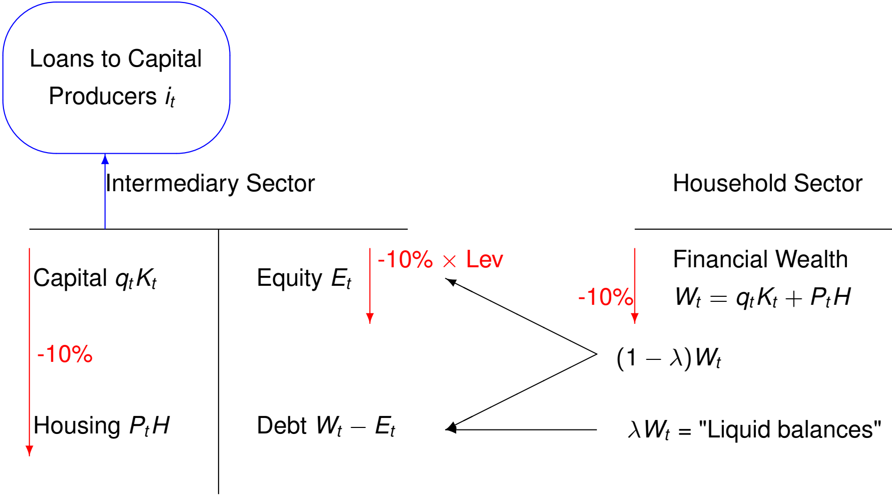
Household Sector

Financial Wealth $W_t = q_t K_t + P_t H$

Aggregate Balance Sheet

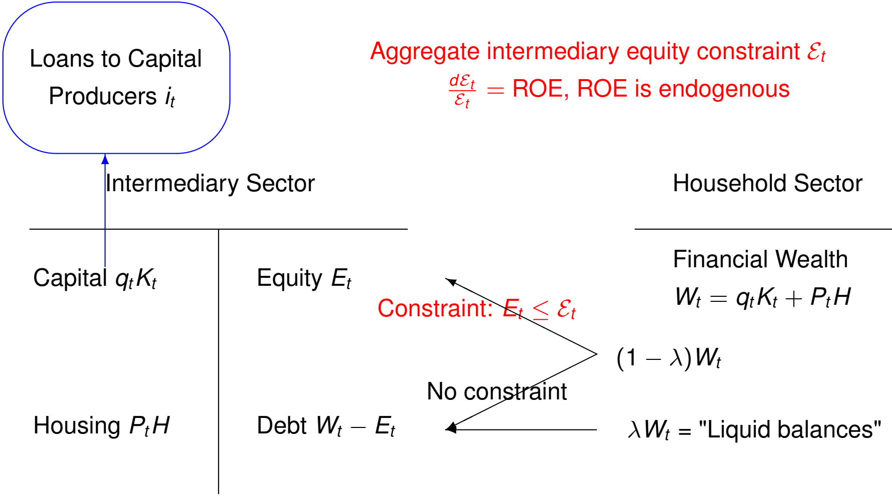


Equity Dynamics in GE



Banker maximizes $E[ROE] - \frac{\gamma}{2} Var[ROE]$

Equity Constraint



Banker maximizes $E[ROE] - \frac{\gamma}{2} Var[ROE]$

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 (ROE)

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

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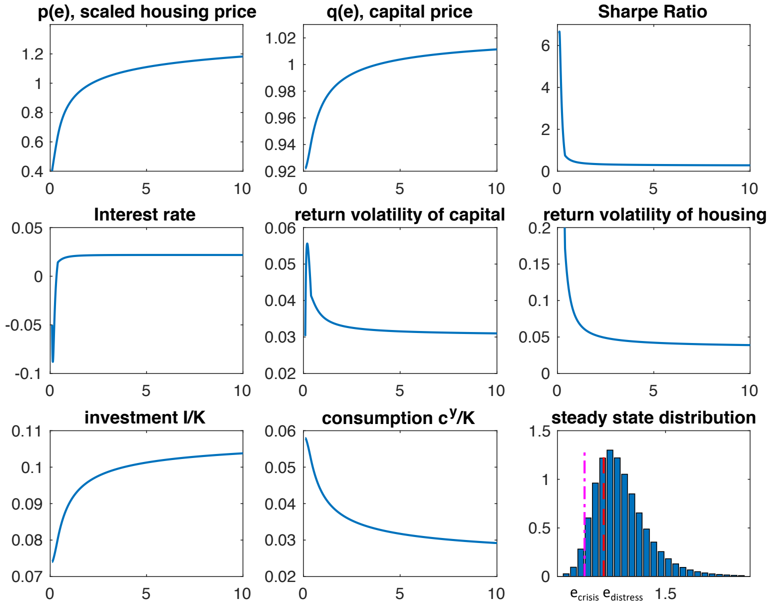
  - ϵ_t as “reputation" of the banker
  - ϵ_t as banker’s “net worth", a function past returns
- Aggregate dynamics of $\mathcal{E}_t = \int \epsilon_t$

Calibration: Baseline Parameters

	Parameter	Choice	Targets (Unconditional)
Panel A: Intermediation			
γ	Banker risk aversion	2	Mean Non-distress Sharpe ratio (model=38%)
λ	Debt ratio	0.75	Average intermediary leverage
η	Banker exit rate	15%	Prob. of crisis (model,data = 3%)
γ	Entry trigger	6.5	Highest Sharpe ratio
β	Entry cost	2.8	Average land price vol (model,data=14%)
Panel B: Technology			
σ	Capital quality shock	3%	Consumption volatility (model=1.66%)
			Note: Model investment vol = 5.2%
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	0.6	Housing-to-wealth ratio

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



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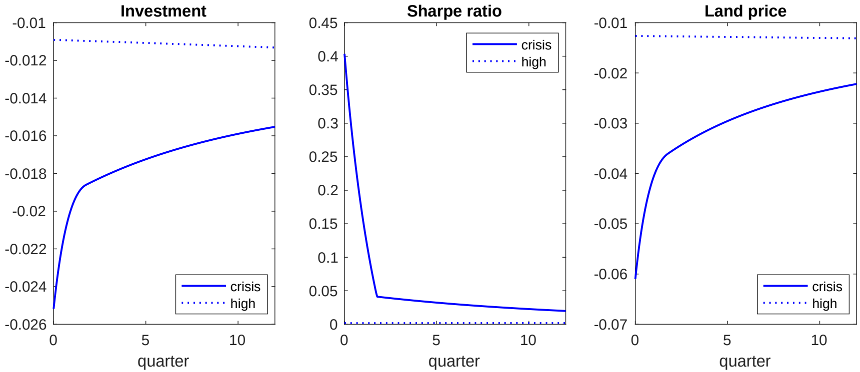


Model simulation and data: Matching asymmetries

	Data	Baseline	$\sigma = 4\%$	$\phi = 0$	$\gamma = 2.3$
Panel A: Distress Periods					
vol(Eq)	25.73	21.68	25.12	9.92	25.62
vol(I)	7.71	6.95	23.36	3.35	8.72
vol(C)	1.72	4.46	6.17	2.31	8.04
vol(PL)	15.44	15.82	17.68		19.03
vol(EB)	65.66	34.56	45.37	6.77	67.34
cov(Eq, I)	1.02	1.12	4.87	0.18	1.95
cov(Eq, C)	0.20	-0.82	-1.14	-0.05	-1.72
cov(Eq, PL)	2.38	3.00	3.86		4.61
cov(Eq, EB)	-8.50	-8.77	-14.24	-0.50	-12.63
Panel B: Non-distress Periods					
vol(Eq)	20.54	5.71	6.59	3.00	7.08
vol(I)	5.79	5.23	12.74	3.01	5.71
vol(C)	1.24	1.66	3.68	2.92	3.12
vol(PL)	9.45	8.23	9.18		8.91
vol(EB)	16.56	5.62	7.95	0.04	20.17
cov(Eq, I)	-0.07	0.30	0.83	0.09	0.37
cov(Eq, C)	-0.01	-0.08	-0.15	0.09	-0.13
cov(Eq, PL)	-0.43	0.47	0.60		0.59
cov(Eq, EB)	0.60	-0.28	-0.54	0.00	-1.15

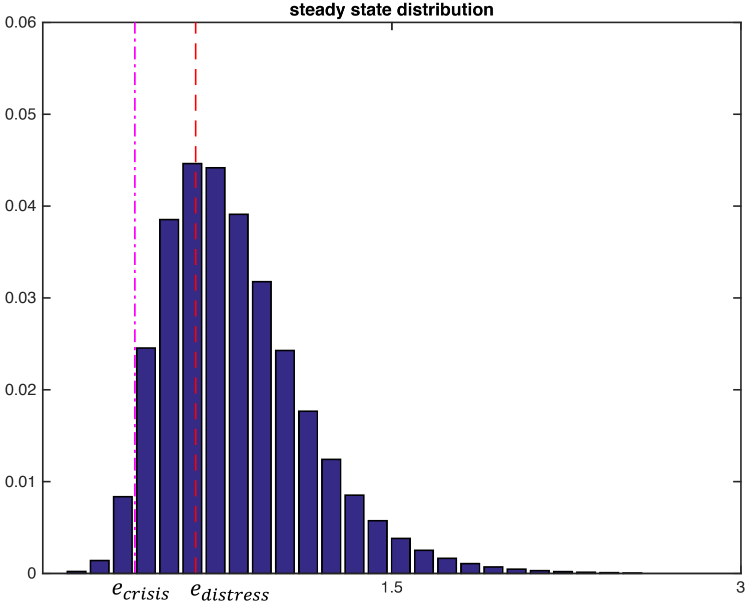
Matching the 2007-2009 Crisis

Pick initial condition for intermediary state variable (e) to match asset prices in 2007Q3

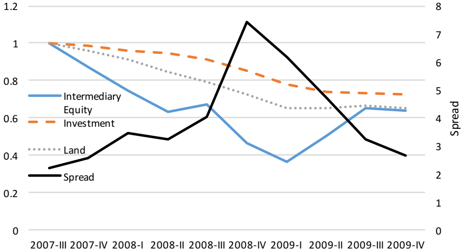
- Asset price = Gilchrist-Zakrajsek credit spread
- Data from 1975 to 2010; compute histogram of spread variable
- Match percentile of spread in the data to the same percentile in model implied distribution for risk premium

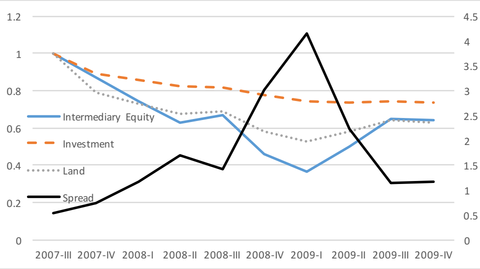
- Answer: In 2007Q3, $e = 0.66$.

Picking initial condition



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





- Set initial condition of $e = 0.66$ in 2007Q3.
- Then choose $(Z_{t+1} - Z_t)$ shocks to match realized intermediary equity series.

07QIV	08QI	08QII	08QIII	08QIV	09QI	09QII	09QIII	09QIV
-5.0%	-1.5	-1.5	-0.9	-2.2	-2.6	-2.5	-0.7	-0.7

  - Total -16.3%. Capital constraint binds after 08Q2—systemic risk state

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

- What is the likelihood of the constraint binding (“systemic crisis") assuming $e = 0.66$ currently (2007Q3):
  - 3% in next 1 years
  - 16% in next 2 years
  - 44% in next 5 years

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: 10%
  - 2 year: 30%
  - 5 year: 57 %

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"

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.