Financial Cycles with Heterogeneous Intermediaries

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Goal of the paper

Provide a framework to analyse jointly monetary policy and financial stability (systemic risk)

- Financial intermediary heterogeneity is a key ingredient
- Changes in the cost of funding generates entry and exit
- Generates time variation in systemic risk, leverage and risk-premia
- Explain some cross-sectional patterns of leverage in data

Contribution

- Dynamic macroeconomic model with financial intermediaries that are heterogeneous in their Value-at-Risk constraints
  - Can generate a meaningful tradeoff between monetary expansion and financial stability
  - Heterogeneity is key in determining asset prices, investment and systemic risk
  - Flexible framework that can be integrated in complex recursive macroeconomic models
  - Opens the door for combining panel data on financial intermediation and theoretical models of financial constraints

Results

- Non-monotonic effects of policies that reduce the cost of funding for intermediaries

- Sign of the effect on systemic risk depends on the level of interest rates
  - High level: systemic risk falls due to entry of less risk taking intermediaries
  - Low level: rise in systemic risk as less risk-taking intermediaries are priced out by more risk-taking ones

- Interaction between the fall in the cost of funding and the fall on asset returns due to leverage increases

Related Literature (subset!)

- **Financial intermediation models:** Danielsson, Shin and Zigrand (2009); Adrian and Shin (2010), Fostel and Geanakoplos (2009), Brunnermeier and Sannikov (2014), He and Krishnamurthy (2013), Nuno and Thomas (2013), Kondor and Vayanos (2014), Kashyap et al. (2014), Suarez and Miera (2014), Adrian and Boyarchenko (2015), Gertler and Kiyotaki (2010), Malherbe (2015)

- **Monetary policy with frictions:** Gertler and Karadi (2011), Gertler, Kiyotaki and Queralto (2011), Aoki, Benigno and Kiyotaki (2015), Bernanke and Gertler (1995), Farhi and Werning (2014, 2015), Curdia and Woodford (2009), Woodford (2015)

- **Risk taking channel:** Borio and Zhu (2008), Bruno and Shin (2014); Jimenez et al. (2014); Miranda-Agrippino and Rey (2015); Morais et al. (2015), Dell' Arricia et al. (2013)

Model

Main ingredients

- Heterogeneous intermediaries collect deposits from households and invest in risky capital or invest in a constant return to scale storage technology
- Aggregate production function with decreasing returns to capital
- Households cannot invest directly in risky projects. They can have deposits or invest in storage technology.
- Government guarantee deposits. They tax (lump sum) households.
- Monetary authority provides wholesale funding (affects the cost of funds)

Model

Heterogeneity in Value at risk constraints

- At least two possible interpretations:
- Differentiated demand by investors
- Regulatory constraints implemented differently across intermediaries. Basel Committee on Banking Supervision provided a test portfolio to a cross section of banks.
- Median implied capital requirements calculated by the banks was about 18 million euros. The minimum was 13 million euros and the maximum was 34 million euros.

Model

Production Function

- Output Y_t is produced according to:

$$Y_t = Z_t K_{t-1}^{\theta} \tag{1}$$

$$\log Z_t = \rho^z \log Z_{t-1} + \varepsilon_t \tag{2}$$

$$\varepsilon_t^z \sim N(0, \sigma_z) \tag{3}$$

where Z_t is total factor productivity. θ is the capital share, ε_t is the shock to the log of exogenous productivity with persistence ρ^z and standard deviation σ_z.

- Firm maximization: $W_t = (1-\theta) Z_t K_{t-1}^{\theta-1}$ and returns on a unit of capital $R_t^k = \theta Z_t K_{t-1}^{\theta-1} + (1-\delta)$.

Financial intermediaries

At the center of the model are financial intermediaries

- Endowment of equity $\omega_t = \omega$ every period
- Buy k_{it} shares in the aggregate capital stock using equity and deposits $q_t^D d_{it}$
- Have limited liability and are subject to a VaR constraint
  - Constrained maximal probability of incurring losses: α^i
  - Heterogeneous across intermediaries: $G(\alpha^i)$

Financial intermediaries

Role of frictions

- Interaction of **limited liability** with different probabilities of default leads to different willingness to pay for risky financial assets
- Due to **deposit guarantees**, depositors do not discriminate based on intermediary default risk

The financial intermediary

Intermediary balance sheets

The intermediary balance sheet:

Assets	Liabilities
k_{it}	ω
	$q_t^D d_{it}$

Net cash flow after returns are realized:

$$\pi_{it} = R_{t+1}^K k_{it} - d_{it}$$

Intermediary problem

The maximization program:

$$\max \mathbb{E}_t^i \left[R_{t+1}^K k_{it} - d_{it} \right]$$
$$\text{s.t.} \;\; \Pr(R_{t+1}^K k_{it} - d_{it} < \omega) \leq \alpha^i$$

- $\mathbb{E}_t^i$ is indexed by i because of limited liability. This truncates the profit function at zero, generating an option value of default that intermediaries can exploit.

Intermediary problem

- An intermediary may participate or not in the market for risky assets. The outside option is the safe storage technology.
- A participating intermediary may use deposits and be levered (value function V_{it}^L)

$$V_{it}^L = E_t[\max(0, R_{t+1}^K k_{it} - d_{it})]$$

- A participating intermediary may also be non-levered (value function V_{it}^N).

$$V_{it}^N = E_t[\max(0, R_{t+1}^K k_{it})]$$

- A non participating intermediary will use the storage technology yielding ω.

Extensive margin

- Entry conditions: an intermediary takes as given the price of deposits q_t^D, the aggregate capital stock K_t, the expected productivity Z_t^e and compares the value of entering the market to its outside option, subject to its value-at-risk contraint.

- An intermediary will participate in the market for risky assets iff $V_{it}^L \geq \omega$ or $V_{it}^N \geq \omega$ and its value-at-risk constraint is satisfied.

Extensive margin

- When $\mathbb{E}_t\left[R^K_{t+1}\right] \geq 1$:
- There is a cutoff α^L_t above which financial intermediaries enter the market for risky projects and lever up to their constraints (**Risky Business Model**).
- Above this cutoff more risk-taking financial intermediaries are all in the market and lever up to their constraints.
- Below the cutoff α^L_t participating intermediaries enter the market for risky projects but do not lever up (**Safe Business Model**).
- Non-levered financial intermediaries invest ω unless their value-at-risk constraint binds in which case they invest an amount $\omega \geq k_{it} \geq 0$.

Intensive margin

- Intermediary i with **risky business model** $(\alpha^i \geq \alpha_t^L)$:

$$k_{it}^L = \omega \frac{1/q_t^D - 1}{1/q_t^D - (1-\delta) - \theta Z_t^{\rho^z} K_t^{\theta-1} \; F^{-1}(\alpha^i)}$$

- Intermediary i with **safe business model**:
  - Unconstrained: $\alpha^i \in [\alpha_t^N, \alpha_t^L]$, with $\alpha^N = \Pr(R_{t+1}^K \omega \leq \omega)$

$$k_{it}^N = \omega$$

  - Constrained: $\alpha^i < \alpha_t^N$

    $k_{it}^N \in [0, \omega]$ given by VaR condition without leverage

Heterogeneous leverage

For participating intermediaries with a risky business model, leverage is given by:

$$\lambda_t^i \equiv \frac{k_{it}^L}{\omega} = \frac{1/q_t^D - 1}{1/q_t^D - (1-\delta) - \theta Z_t^{\rho^z} K_t^{\theta-1} \; F^{-1}(\alpha^i)}$$

Conditional on participation, λ_t^i is:

- Increasing in intermediary risk-taking α^i
- Decreasing in cost of leverage: $1/q_t^D$
- Increasing in expected returns: $\theta Z_t^{\rho^z} K_t^{\theta-1} + (1-\delta)$

Financial market equilibrium

To close the financial market equilibrium, we need to use the market clearing condition.

$$K_t = \int_{\underline{\alpha}}^{\alpha_t^L} k_{it}^N \, dG(\alpha^i) + \int_{\alpha_t^L}^{\overline{\alpha}} k_{it}^L \, dG(\alpha^i) \tag{4}$$

- The financial block is described by the joint dynamics of $(\alpha_t^L, q_t, Z_t^e, K_t)$.
- Taking q_t^D as given, we can solve for the equilibrium aggregate capital stock and the cut off.

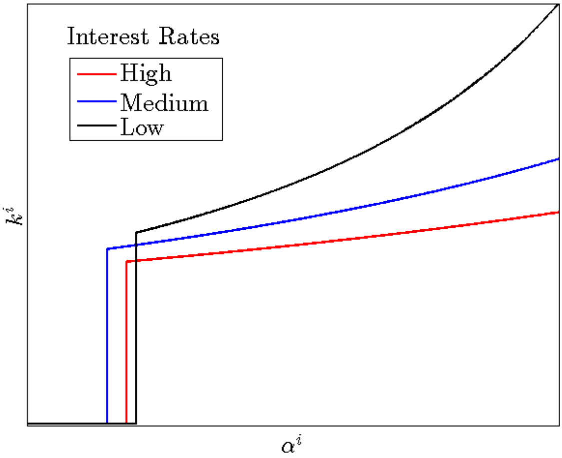
Systemic Risk

The model allows a precise definition of systemic risk

- We can quantify systemic risk as the probability that a certain fraction of intermediaries defaults or in terms of a fraction of the assets.

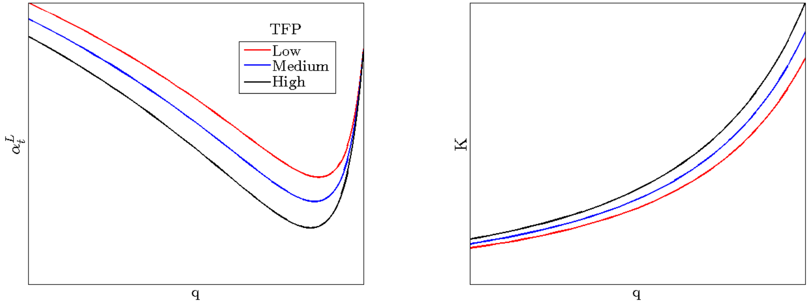
- For example the cutoff α^L gives the probability that the entire leveraged part of the financial system incurs in losses at a point in time.

Partial Equilibrium



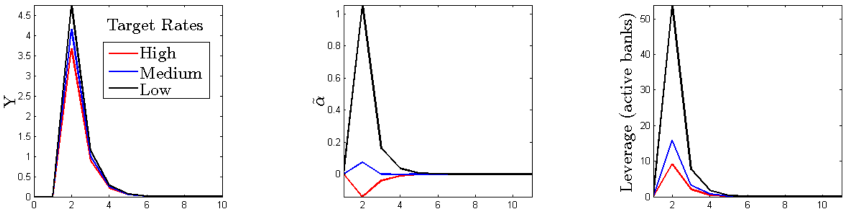
Cross-sectional distribution of leverage

Partial equilibrium



Cut-off and aggregate capital as a function of deposit costs

Partial Equilibrium



IRFs to a 100 bp shock to deposit rates (% changes)

$$R_t = \bar{R}^{1-\nu} R_{t-1}^{\nu} \varepsilon_t^R$$

Monetary policy

Monetary policy affects composition of financial sector

- Cheap credit lines reduce static risk of default
  $\Rightarrow$ *But allow each intermediary to lever more*
- And also affects the extensive margin
  $\Rightarrow$ *More intermediaries start leveraging*
  $\Rightarrow$ *Or stop if marginal returns decrease a lot*
- Impacts ability and willingness of intermediaries to lend
- Affects the risk premium and risk-shifting

There is a meaningful tradeoff for some values of the interest rate between monetary policy and financial stability policy.

Cross-sectional implications and evidence

The model has the following properties:

1. Aggregate leverage is monotonically decreasing with R
   - And so is its derivative

   $\Rightarrow$ **When R is low, leverage is higher**

2. Skewness is monotonically decreasing with R
   - And again so is its derivative

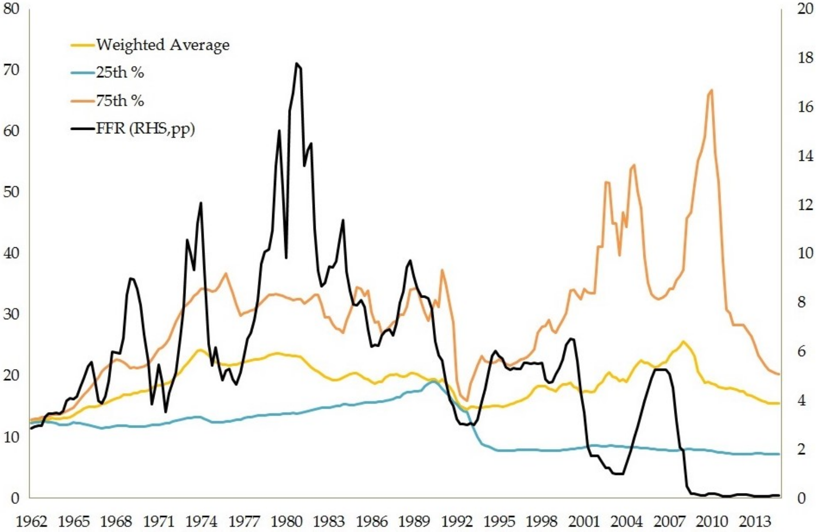
   $\Rightarrow$ **When R is low, capital will be even more concentrated on the upper range of the risk-taking distribution**

3. More leveraged intermediaries are more risk-taking

   $\Rightarrow$ **Profit volatility, betas and leverage are correlated**

Cross-sectional implications and evidence

1. Aggregate leverage and R

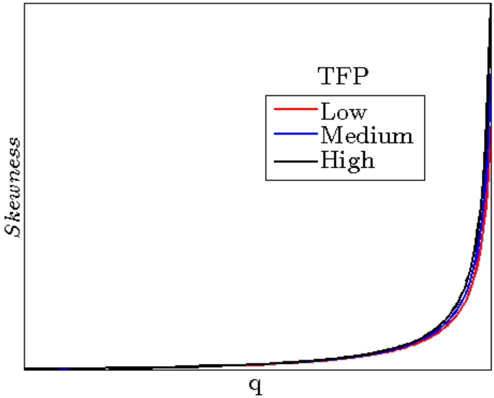


Balanced

Cross-sectional implications and evidence

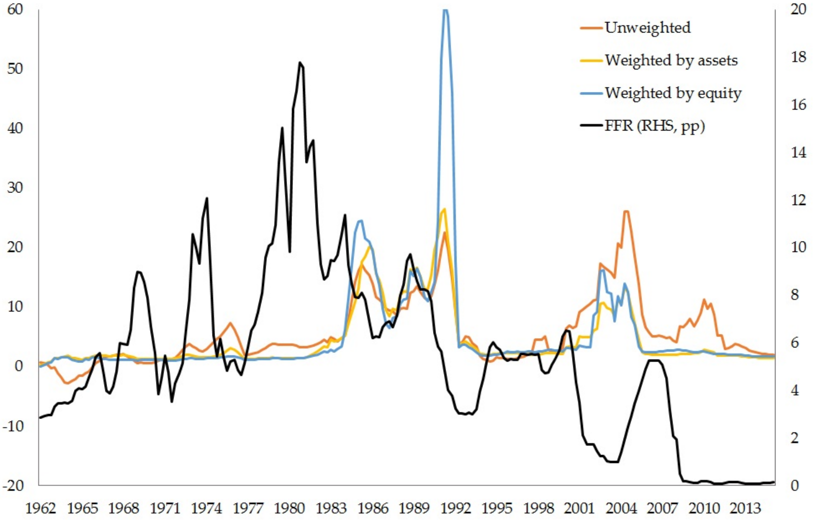
2. Cross-sectional skewness and R

Skewness in the model as a function of the cost of leverage $(1/R)$:



Cross-sectional implications and evidence

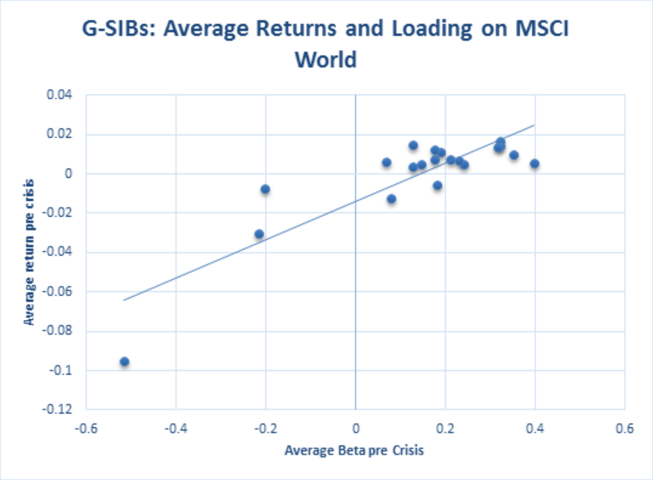
2. Cross-sectional skewness and R



Cross-sectional skewness of leverage and Fed Funds Rate Balanced

Cross-sectional implications and evidence

3. Profit volatility, market betas and leverage



General Equilibrium

- Partial eq: q_t^D assumed to be exogenous
- General eq: q_t^D is the price that clears the market for funds
  - Household supply of deposits used to pin down q^D in equilibrium

- Households are assumed to be able to both invest in deposits and storage
  - ...but not directly in the capital stock
  - Also provide a fixed supply of labour and pay lumpsum taxes

General equilibrium

Households

$$\max_{\{C_t, S_t^H, D_t^H\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^H) \qquad \text{s.t.}$$

$$C_t^H + q_t^D D_t^H + S_t^H = D_{t-1}^H + S_{t-1}^H + W_t - T_t \qquad \forall_t$$

Integrating monetary policy with the intermediary problem

Monetary policy: Intermediaries now have also access to wholesale funding l_{it}

$$k_{it} = \omega + q_t^D d_{it} + q_t^L l_{it}$$

Monetary policy

Assumption 1: Up to λ units of funding per unit of deposits d^i

$$l_{it} = \lambda d_{it}$$

Assumption 2: Funds are provided at a spread from deposit rates

$$q_t^L = (1 + \gamma_t) q_t^D$$

Assumption 3: Deep-pocketed monetary authority

- Internal asset management not modelled
  - Can always fund wholesale funding
  - Interest differential is deadweight loss/gain

Monetary policy

Intermediary balance sheets

Assets	Liabilities
k_{it}	ω
	$q_t^D d_{it}$
	$q_t^L l_{it}$

Monetary policy

Intermediary balance sheets

Assets	Liabilities
k_{it}	ω
	$q_t^D d_{it}$
	$q_t^D (1+\gamma_t)\lambda d_{it}$

Monetary policy

Intermediary balance sheets

Assets	Liabilities
k_{it}	ω
	$q_t^f f_{it}$

Monetary policy

Intermediary balance sheets

Assets	Liabilities
k_{it}	ω
	$q_t^f f_{it}$

with

$$q_t^F = q_t^D \frac{1+\lambda(1+\gamma_t)}{1+\lambda}$$
$$f_{it} = d_{it}(1+\lambda)$$

Intermediary problem is then the same, but now there is a wedge

- Between deposit rates and the cost of funding
- Between total deposits and total funding

General equilibrium

Financial sector equilibrium

- We first solve for the financial sector equilibrium on a grid of (q, Z^e).

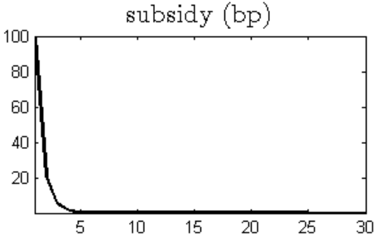
General equilibrium block

- First we discretize the state space using a Tauchen-Hussey procedure for the AR(1) processes (Z, γ)
- Guess q_0^D and set storage policy function $S_0 = 0$
- Obtain capital and deposits from the financial sector block
- Update prices using the consumer Euler Equation.
- Iterate until convergence

Monetary policy and systemic risk

We now compare the IRFs at 3 different parts of the state space:

- **Scenario 1:** Starting with large $K \Rightarrow$ "low" R^D
- **Scenario 2:** Starting with low $K \Rightarrow$ "high" R^D
- **Scenario 3:** Starting with $K = \bar{K} \Rightarrow$ "average" R^D



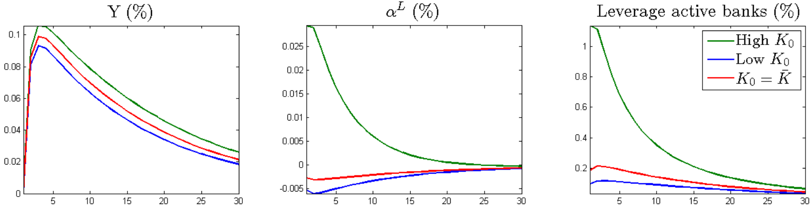
Monetary policy shock of 100 basis points to subsidy γ_t

Calibration

Parameter	Value	Description
ψ	4	Risk aversion parameter
β	0.95	Subjective discount factor
ρ^z	0.9	AR(1) parameter for TFP
σ_z	0.028	Standard deviation of TFP shock
μ^γ	0.02	Target spread over deposit rates
ρ^γ	0.24	Spread persistence
σ_γ	0.01	Standard deviation of spread
$\frac{\lambda}{1+\lambda}$	0.3	Central Bank funding percentage
θ	0.35	Capital share of output
δ	0.1	Depreciation rate
ω	0.5	Equity of intermediaries
$\overline{\alpha}$	0.1	Upper bound of distribution $G(\alpha^i)$

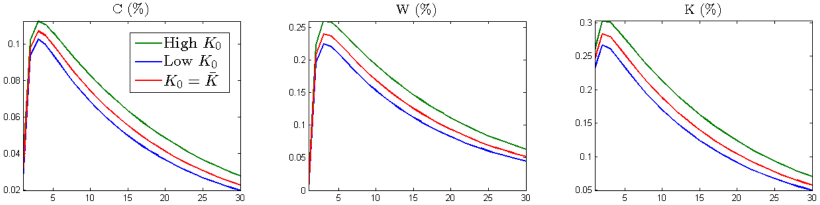
IRF to monetary policy shock

Key variables



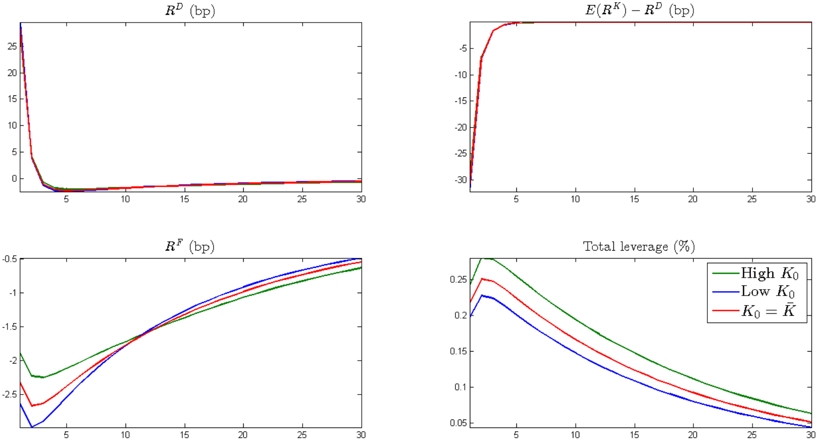
IRF to monetary policy shock

Real variables

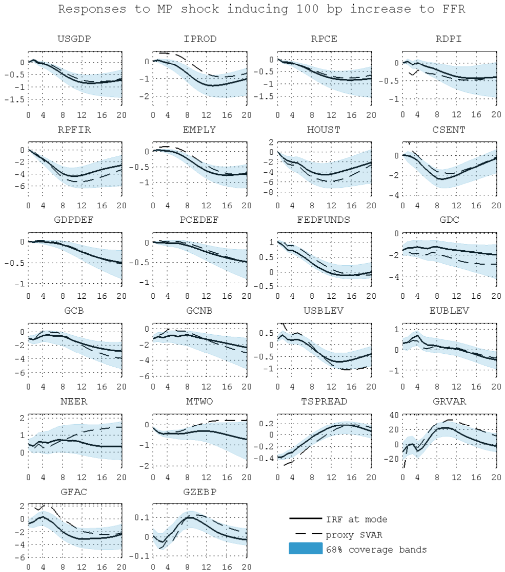


IRF to monetary policy shock

Financial variables



BVAR results



Empirical evidence

- Literature finds evidence of risk taking channel of monetary policy. Banks take on more risk when the interest rate decreases: Dell Arricia et al. (2013), Jimenez et al (2014), Morais et al. (2015)

- Dell Arricia et al. (2013) also finds that the more leveraged banks take the most risk when the interest rate decreases.

- This is consistent with the implications of our model.

Systemic crises and efficiency losses: costly default

- When intermediaries cannot repay their deposits:
  - Government taxes households
  - Repays deposit insurance
- Now, we assume that ROA of distressed intermediaries suffer an efficiency loss $\overline{\Delta}$
- Crisis might also affect productivity in following periods
  - Poisson shock ξ determines if economy remains distressed
  - If yes, productivity loss is proportional to the mass of capital held by defaulting intermediaries μ_t^D
  - Scaled by the maximal loss: $\overline{\Delta}$

Calibration

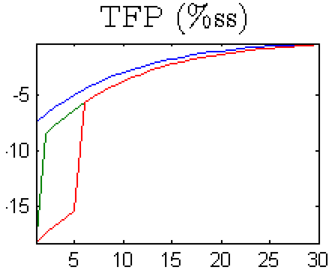
Parameter	Value	Description
ψ	4	Risk aversion parameter
β	0.95	Subjective discount factor
ρ^z	0.9	AR(1) parameter for TFP
σ_z	0.028	Standard deviation of TFP shock
μ^γ	0.02	Target spread over deposit rates
ρ^γ	0.24	Spread persistence
σ_γ	0.01	Standard deviation of spread
$\frac{\lambda}{1+\lambda}$	0.3	Central Bank funding percentage
θ	0.35	Capital share of output
δ	0.1	Depreciation rate
ω	0.5	Equity of intermediaries
$P(\xi = 1)$	0.5	Average crisis length of 2 years
$\overline{\Delta}$	0.05	Maximum efficiency loss of 5%
$\overline{\alpha}$	0.1	Upper bound of distribution $G(\alpha^i)$

Systemic crises and productivity shocks

We now compare the IRFs of 3 scenarios:

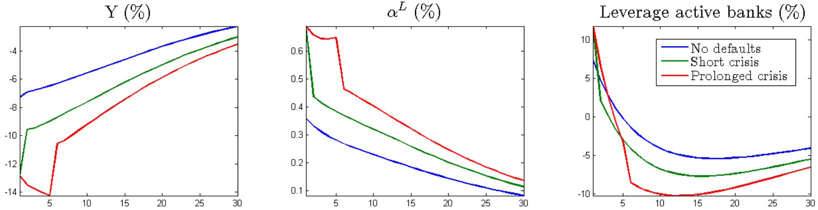
- **Scenario 1:** Largest negative productivity shock that doesn't trigger defaults

- **Scenarios 2 and 3:** Smallest negative shock such that all leveraged intermediaries default
  - **Scenario 2:** Crisis does not carry on: $\xi_t = 0$
  - **Scenario 3:** Crisis last for 5 periods: $\xi_s = 1$, $\forall_{s \in [t, t+3]}$



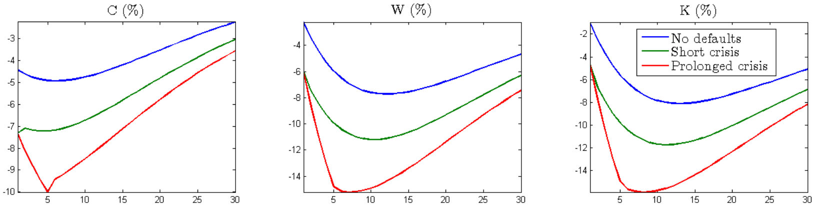
IRF to large productivity shocks

Key variables



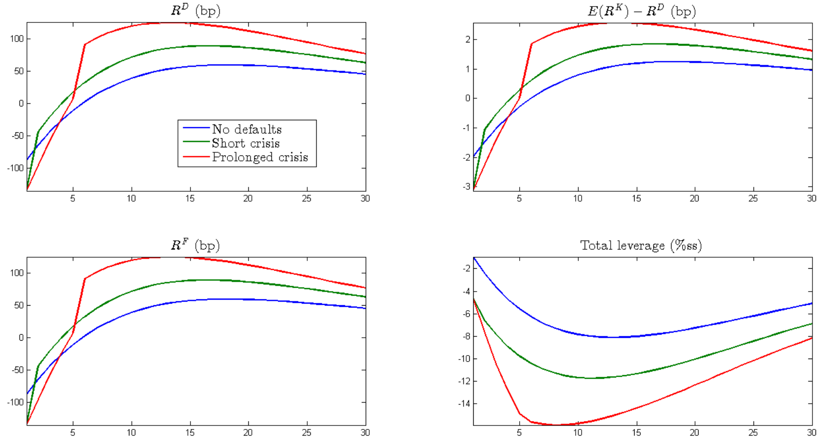
IRF to large productivity shocks

Real variables



IRF to large productivity shocks

Financial variables



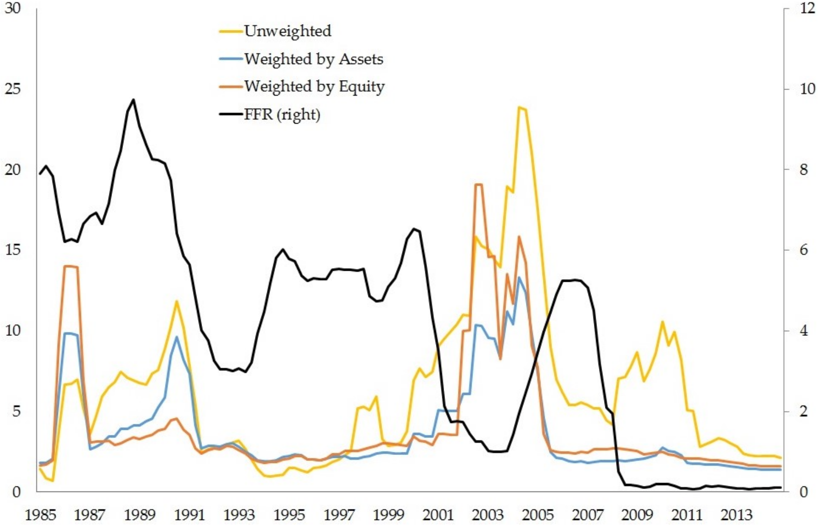
Conclusion

A new framework with heterogeneous financial intermediaries

- Generates endogenous entry and exit in risky financial markets
- Time variation in leverage, risk-shifting and systemic risk
- Trade-off between monetary policy and financial stability
  - But only when rates are low.
- Fits recent cross-sectional patterns in leverage and risk-taking
- Versatile: potential applications include international capital flows; real estate markets

Additional Figures

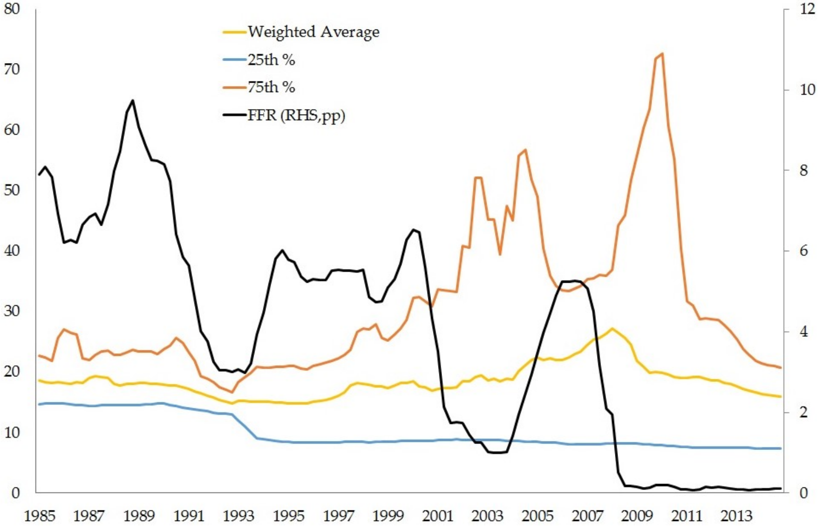
Cross-sectional skewness and R - Balanced panel



Cross-sectional skewness of leverage and Fed Funds Rate Back

Cross-sectional implications and evidence

1. Aggregate leverage and R



Back