A Model of Financial Intermediation

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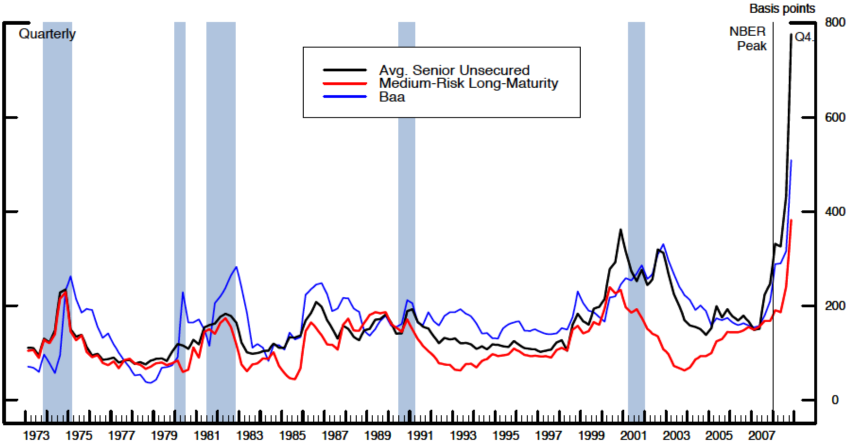
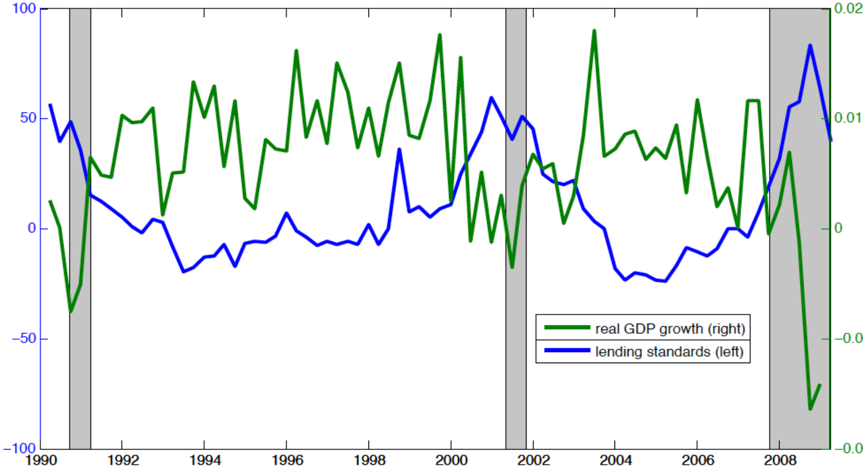
A Model with Financial Intermediation

- Previous models have a very streamlined financial intermediation structure.
- Many of the events of the 2007-2010 recession were about breakdowns in intermediation.
- Kiyotaki and Gertler (2011) incorporate a richer financial intermediation sector.
- In particular, we will deal with liquidity.
- Different concepts of liquidity.
- Help us to think about unconventional monetary policy.

Figure 1: Selected Corporate Bond Spreads



NOTE: The black line depicts the average credit spread for our sample of 5,269 senior unsecured corporate bonds; the red line depicts the average credit spread associated with very long maturity corporate bonds issued by firms with low to medium probability of default (see text for details); and the blue line depicts the standard Baa credit spread, measured relative to the 10-year Treasury yield. The shaded vertical bars denote NBER-dated recessions.


100
50
0
−50
−100
0.02
0.01
0
−0.0
−0.0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
real GDP growth (right)
lending standards (left)

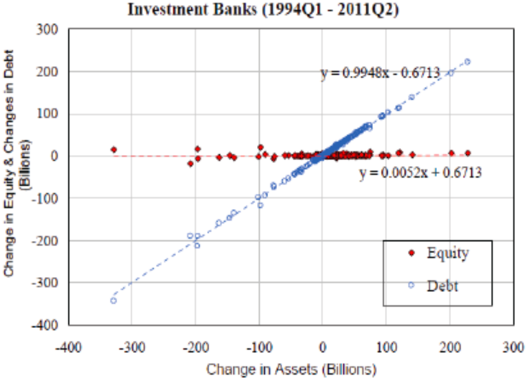


Figure 2: Scatter chart of $\{(\Delta A_t, \Delta E_t)\}$ and $\{(\Delta A_t, \Delta D_t)\}$ for changes in assets, equity and debt of US investment bank sector consisting of Bear Stearns, Goldman Sachs, Lehman Brothers, Merrill Lynch and Morgan Stanley between 1994Q1 and 2011Q2 (Source: SEC 10Q filings).

Representative Household

- Preferences:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log \left(c_t - \gamma c_{t-1} \right) - \chi \frac{l_t^{1+\vartheta}}{1+\vartheta} \right)$$

- Household can save in:

1. Deposits at the financial intermediary, d_t, that pay an uncontingent nominal gross interest rate R_t.
2. Public debt, d_{gt}, that pay an uncontingent nominal gross interest rate R_t.
3. Arrow securities (net zero supply in equilibrium).

- The budget constraint is then:

$$c_t + d_{h,t} = w_t l_t + R_{t-1} d_{h,t-1} + T_t + F_t$$

where $d_{h,t} = d_t + d_{gt}$.

Representative Household

- Continuum of members of measure one with perfect consumption insurance within the family.
- A fraction $1 - f$ are workers and f are bankers.
- Workers work and send wages back to the family.
- Bankers run a bank that sends (non-negative) dividends back to the family.
- In each period, a fraction $(1 - \sigma)$ of bankers become workers and a fraction $(1 - \sigma) \frac{f}{1-f}$ of workers become bankers. Why?

Optimality Conditions

- The first-order conditions for the household are:

$$\frac{1}{c_t - \gamma c_{t-1}} - \beta \mathbb{E}_t \frac{\gamma}{c_{t+1} - \gamma c_t} = \lambda_t$$
$$\lambda_t = \beta \mathbb{E}_t \lambda_{t+1} R_t$$
$$\chi l_t^{\vartheta} = \lambda_t w_t$$

- Asset pricing kernel:

$$SDF_t = \beta \frac{\lambda_t}{\lambda_{t-1}}$$

and standard non-arbitrage conditions.

Technology

- Island model: continuum of islands of measure 1.
- In each island, there is a firm that produces the final good with capital (not mobile) and labor (mobile across islands) and a Cobb-Douglas production function.
- Then, by equating the capital-labor ratio across islands, aggregate output is:

$$y_t = A_t k_t^{\alpha} l_t^{1-\alpha}$$

  where A_t is a random variable.
- Wages satisfy:

$$w_t = (1 - \alpha) \frac{y_t}{l_t}$$

- Profits per unit of capital:

$$z_t = \frac{y_t - w_t l_t}{k_t}$$

Liquidity Risk

- Each period, investment opportunities arrive randomly to a fraction π^i of islands.
- There is no opportunity in $\pi^n = 1 - \pi^i$.
- Investment opportunities are i.i.d. across time and islands.
- Only firms in islands with investment opportunities can accumulate capital.
- Then:

$$
\begin{aligned}
k_{t+1} &= \psi_{t+1}\left[\pi^i (1-\delta) k_t + i_t\right] + \psi_{t+1}\pi^n (1-\delta) k_t \\
&= \psi_{t+1}\left[(1-\delta) k_t + i_t\right]
\end{aligned}
$$

where ψ_{t+1} is a shock to productivity of capital.

Capital Good Producers

- Adjustment costs in investment:

$$f\left(\frac{i_t}{i_{t-1}}\right)$$

with $f(1) = f'(1) = 0$ and $f''\left(\frac{i_t}{i_{t-1}}\right) > 0$.

- Relative price of capital: q_t^i.
- Capital good producers:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0}\left(q_t^i - \left(1 + f\left(\frac{i_t}{i_{t-1}}\right)\right) i_t\right)$$

- Optimality condition:

$$q_t^i = 1 + f\left(\frac{i_t}{i_{t-1}}\right) + \frac{i_t}{i_{t-1}} f'\left(\frac{i_t}{i_{t-1}}\right) - \mathbb{E}_t \beta \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{i_{t+1}}{i_t}\right)^2 f'\left(\frac{i_{t+1}}{i_t}\right)$$

Aggregate Resource Constraint

- Government consumption g_t.
- Then:

$$y_t = c_t + \left(1 + f\left(\frac{i_t}{i_{t-1}}\right)\right) i_t + g_t$$

- We will also have, later on, a wide set of policies, that will imply a relatively involved government budget constraint.
- I will skip details because it is mere accounting.

Banks I

- Banks are born with a small initial transfer from the family.
- Initial equity is increased with retained earnings.
- Dividends are only distributed when the bank dies.
- Banks are attached to a particular island, which in this period may be $h = \{i, n\}$.
- Thus, ex post, they may not be able to lend$\Rightarrow$wholesale market.

Banks II

- Banks move across islands over time to equate expected rate of return:
  1. Before moving, they sell their loans.
  2. This allows us to forget about distributions: ratio of total financial intermediary net worth to total capital is the same in each island.
- Discussion: specificity in bank relational capital?

Balance Sheet

- Net worth: n_t^h.
- Besides equity, banks raise funds in a national financial market:
  1. Retail market: from the households, d_t at cost R_t. Before investment shock is realized.
  2. Wholesale market: from each other, b_t^h at cost R_{bt}. After investment shock is realized.
- Then, bank lend to non-financial firms in their island s_t^h. No enforcement problem (we can think about s_t^h as equity).

Flow-of-Funds I

- Balance sheet constraint (where q_t^h is the price of a loan):

$$q_t^h s_t^h = n_t^h + b_t^h + d_t$$

- Evolution of net worth:

$$n_t^h = \left[z_t + (1-\delta)\, q_t^h \right] \psi_t s_{t-1}^h - R_{t-1} d_{t-1} - R_{bt-1} b_{t-1}^h$$

- Objective function of bank:

$$V_t = \mathbb{E}_t \sum_{i=1}^{\infty} (1-\sigma)\, \sigma^{i-1} \beta^i \frac{\lambda_{t+i}}{\lambda_t} n_{t+i}^h$$

Flow-of-Funds II

- Value function: maximized objective function:

$$V_t\left(s_t^h, b_t^h, d_t\right) = \max V_t$$

$$= \mathbb{E}_t \beta^t \frac{\lambda_{t+i}}{\lambda_t} \sum_h \pi^h \left\{ \begin{array}{c} (1-\sigma)\, n_{t+1}^h \\ +\sigma \max_{d_{t+1}} \max_{s_t^h, b_t^h} V_t\left(s_{t+1}^h, b_{t+1}^h, d_{t+1}\right) \end{array} \right\}$$

Financial Friction I

- We need some financial friction to make the intermediation problem interesting.

- Simply costly-enforcement mechanism.

- Diversion of funds to family:

$$\theta \left(q_t^h s_t^h - \omega b_t^h \right)$$

  default, and close down.

- Interpretation of ω.

Financial Friction II

- Three cases:

1. $\omega = 1$ (frictionless interbank market). The interbank and loan rates are the same. They are bigger than the deposit rate if banks are constrained (only one aggregate constrain holds).

2. $\omega = 0$ (symmetric frictions). The interbank and deposit rate are the same. The returns on loans if banks on non-investing islands are constrained.

3. $\omega \in (0, 1)$. The interbank rate lies between the return on loans and the deposit rate.

Incentive Constraint

- Then, the incentive constraint (IC) is:

$$V_t\left(s_t^h, b_t^h, d_t\right) \geq \theta\left(q_t^h s_t^h - \omega b_t^h\right)$$

- The Lagrangian associated with the IC is λ_t^h and:

$$\overline{\lambda}_t^h = \pi^i \lambda_t^i + \pi^n \lambda_t^n$$

- Problem:

$$\max V_t\left(s_t^h, b_t^h, d_t\right) + \overline{\lambda}_t^h\left(V_t\left(s_t^h, b_t^h, d_t\right) - \theta\left(q_t^h s_t^h - \omega b_t^h\right)\right)$$
$$= \max\left(1 + \overline{\lambda}_t^h\right) V_t\left(s_t^h, b_t^h, d_t\right) - \overline{\lambda}_t^h \theta\left(q_t^h s_t^h - \omega b_t^h\right)$$

Guess of Value Functions

- We guess that value function is linear in states:

$$V\left(s_t^h, b_t^h, d_t\right) = \nu_{st} s_t^h - \nu_{bt} b_t^h - \nu_{dt} d_t$$

- Interpretation of coefficients:

  1. ν_{st}: marginal value of assets.
  2. ν_{bt}: marginal cost of interbank borrowing.
  3. ν_{dt}: marginal cost of deposits.

- Then:

$$\left(1 + \overline{\lambda}_t^h\right)\left(\nu_{st} s_t^h - \nu_{bt} b_t^h - \nu_{dt} d_t\right) - \overline{\lambda}_t^h \theta \left(q_t^h s_t^h - \omega b_t^h\right)$$

Optimality Conditions

- Remember that, from the balance sheet constraint:

$$b_t^h = q_t^h s_t^h - n_t^h - d_t$$

- The FOC are (note the bank takes n_t^h as given and use chain rule to take derivatives of b_t^h):

$$d_t: \quad \left(1 + \overline{\lambda}_t^h\right) \left(\nu_{bt} - \nu_{dt}\right) = \overline{\lambda}_t^h \theta \omega$$

$$s_t^h: \quad \left(1 + \overline{\lambda}_t^h\right) \left(\frac{\nu_{st}}{q_t^h} - \nu_{bt}\right) = \overline{\lambda}_t^h \theta \left(1 - \omega\right)$$

$$\lambda_t^h: \ \nu_{dt} n_t^h \geq \left(\theta - \left(\frac{\nu_{st}}{q_t^h} - \nu_{dt}\right)\right) q_t^h s_t^h - \left(\theta\omega - \left(\nu_{bt} - \nu_{dt}\right)\right) b_t^h$$

Reading the Optimality Conditions

- Interpretation:

  1. Marginal cost of interbank borrowing is higher than cost of deposits iff $\overline{\lambda}_t^h > 0$ and $\omega > 0$.

  2. Marginal value of assets is higher than marginal cost of interbank borrowing if $\lambda_t^h > 0$ and $\omega < 1$.

  3. Balance sheet effect: equity in bank must be sufficiently high in relation with assets and interbank borrowing.

Case A: Frictionless Wholesale Financial Market I

- $\omega = 1$.
- Arbitrage across asset markets:

$$q_t^b = q_t^l = q_t$$

- Marginal value of asset must be equal to the marginal cost of borrowing on the interbank market

$$\frac{\nu_{st}}{q_t} = \nu_{bt}$$

- The incentive constraint is simply:

$$q_t s_t - b_t = \phi_t n_t$$

where

$$\phi_t = \frac{\nu_t}{\theta - \mu_t}$$

Case A: Frictionless Wholesale Financial Market II

- With a bit of work (which I skip), and by matching coefficients

$$\mu_t = \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1} \left(R^k_{t+1} - R_{t+1} \right)$$

$$\nu_t = \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1} R_{t+1}$$

where

$$\Omega_{t+1} = 1 - \sigma + \sigma \left(\nu_{t+1} + \phi_{t+1} \mu_{t+1} \right)$$

$$R^k_{t+1} = \psi_t \frac{z_{t+1} + (1 - \delta) q_{t+1}}{q_t}$$

- Aggregating:

$$q_t s_t = \phi_t n_t$$

- In this economy, a crisis increases the excess returns for banks of all types.

Case B: Symmetric Frictions I

- $\omega = 0$.
- Deposits and interbank loans become perfect substitutes:

$$\nu_t = \nu_{bt}$$

- Thus, in general, there will be differences in prices of assets across islands:

$$q_t^n > q_t^i$$

and

$$\mu_t^i > \mu_t^n \geq 0$$

Case B: Symmetric Frictions II

- The leverage ratio:

$$\frac{q_t^i s_t^i}{n_t^i} = \phi_t^i = \frac{\nu_t}{\theta - \mu_t^i}$$

$$\frac{q_t^n s_t^n}{n_t^n} \leq \phi_t^n = \frac{\nu_t}{\theta - \mu_t^n}$$

$$\left(\frac{q_t^n s_t^n}{n_t^n} - \phi_t^n \right) \mu_t^n = 0$$

- With a bit of work (which I skip), and by matching coefficients

$$\mu_t = \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^{h'} \left(R_{t+1}^{hh'} - R_{t+1} \right)$$

$$\nu_t = \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^{h'} R_{t+1}$$

Case B: Symmetric Frictions III

where

$$\Omega_{t+1}^{h'} = 1 - \sigma + \sigma \left(\nu_{t+1} + \phi_{t+1}^{h'} \mu_{t+1}^{h'} \right)$$

$$R_{t+1}^{hh'} = \psi_t \frac{z_{t+1} + (1-\delta) q_{t+1}^{h'}}{q_t^h}$$

- Note that know we need to index also by the type of the island in next period and integrate over it.

- Aggregating:

$$q_t^i s_t^i = \phi_t^i n_t^i$$

$$q_t^n s_t^n \leq \phi_t^n n_t^n$$

$$\left(q_t^n s_t^n - \phi_t^n n_t^n \right) \mu_t^n = 0$$

Case B: Symmetric Frictions IV

- In this economy, a crisis increases the excess returns for banks of all types.
- Also:

$$
\begin{aligned}
& \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^{h'} R_{kt+1}^{ih'} \\
> & \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^{h'} R_{kt+1}^{nh'} \\
\geq & \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^{h'} R_{bt+1} \\
= & \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^{h'} R_{t+1}
\end{aligned}
$$

Aggregation

- Total bank net worth:

$$n_t^h = n_{ot}^h + n_{yt}^h$$

- Total net worth of old banks:

$$n_{ot}^h = \sigma\pi^h \left\{ \left[z_t + (1-\delta)\, q_t^h \right] \psi_t s_{t-1} - R_{t-1} d_{t-1} \right\}$$

where we have net out the interbank loans.

- Total net worth of new banks:

$$n_{yt}^h = \xi \left[z_t + (1-\delta)\, q_t^h \right] \psi_t s_{t-1}$$

- Aggregate balance sheet constraint:

$$d_t = \sum_{h=i,n} \left(q_t^h s_t^h - n_t^h \right)$$

Market Clearing

- Market for securities:

$$s_t^i = i_t + (1-\delta)\,\pi^i k_t$$
$$s_t^n = (1-\delta)\,\pi^n k_t$$

- Labor market

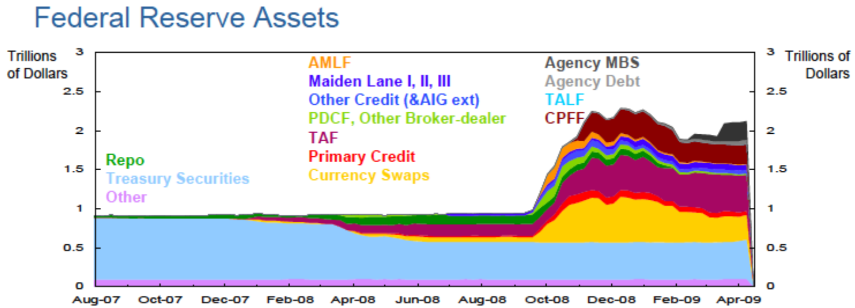
$$\chi l_t^{\vartheta} = \lambda_t w_t$$

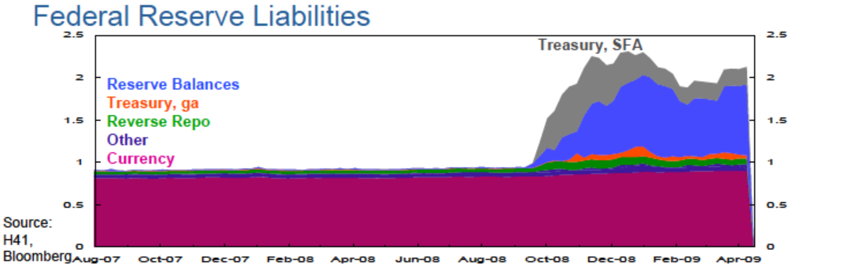
- Debt market:

$$d_{ht} = d_t + d_g$$

Policy Experiments

- Unconventional monetary policy:
  1. Lending facilities.
  2. Liquidity facilities.
  3. Equity injections.
- Classic discussion from Sargent and Wallace (1983): real bills doctrine.
- How do we decide between these different policies?
- Effect on government budget position.


Federal Reserve Assets
Trillions of Dollars
Trillions of Dollars
3
2.5
2
1.5
1
0.5
0
AMLF
Maiden Lane I, II, III
Other Credit (&AIG ext)
PDCF, Other Broker-dealer
TAF
Primary Credit
Currency Swaps
Agency MBS
Agency Debt
TALF
CPFF
Repo
Treasury Securities
Other
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Aug-08
Oct-08
Dec-08
Feb-09
Apr-09


Federal Reserve Liabilities
2.5
2
1.5
1
0.5
0
Treasury, SFA
Reserve Balances
Treasury, ga
Reverse Repo
Other
Currency
Source: H41, Bloomberg
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Aug-08
Oct-08
Dec-08
Feb-09
Apr-09

SEALING OF THE BANK OF ENGLAND CHARTER. 1694.

SIR JOHN HOUBLON. *Governor.* SIR JOHN SOMERS. *Lord Keeper.* MR. MICHAEL GODFREY *Deputy Governor.*

Lending Facilities

- The central bank lends directly to banks that are constrained.
- Central bank is not constrained by its balance sheet (this is more subtle than it seems, but let us assume it for a moment).
- But additional cost τ of underwriting a loan (monitoring, politics...).
- The central bank does not subsidize loans...
- ...but, by increasing funds available, it has an impact on equilibrium prices and allocations.
- New equilibrium condition:

$$q_t^h s_t^h = q_t^h \left(s_{pt}^h + s_{gt}^h \right)$$

Liquidity Facilities

- Central bank discounts loans from the interbank lending market.

- Banks can divert less funds from the central bank than from the regular interbank market:

$$\theta\left(1-\omega_g\right)$$

  with $\omega_g > 0$.

- Then:

$$q_t^h s_t^h = n_t^h + b_t^h + m_t^h + d_t$$

- Penalty rate for discount: difference in the default.

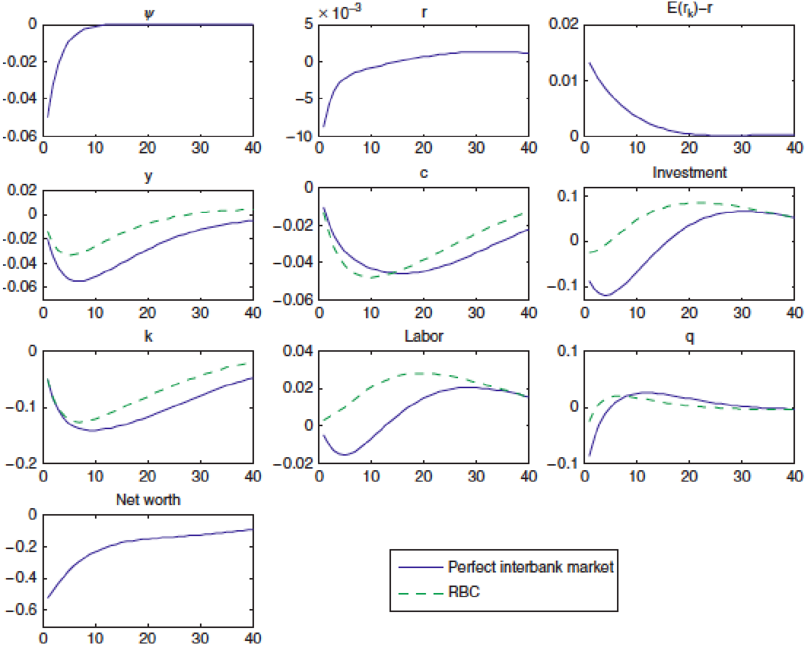
Equity Injections

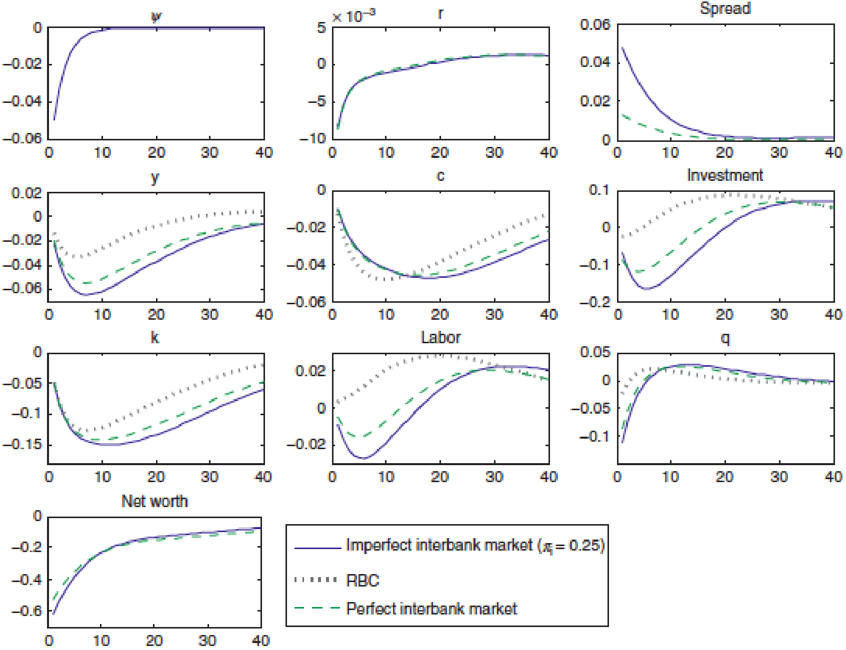
- Treasury transfers wealth to banks.
- Government takes direct ownership position.
- Then:

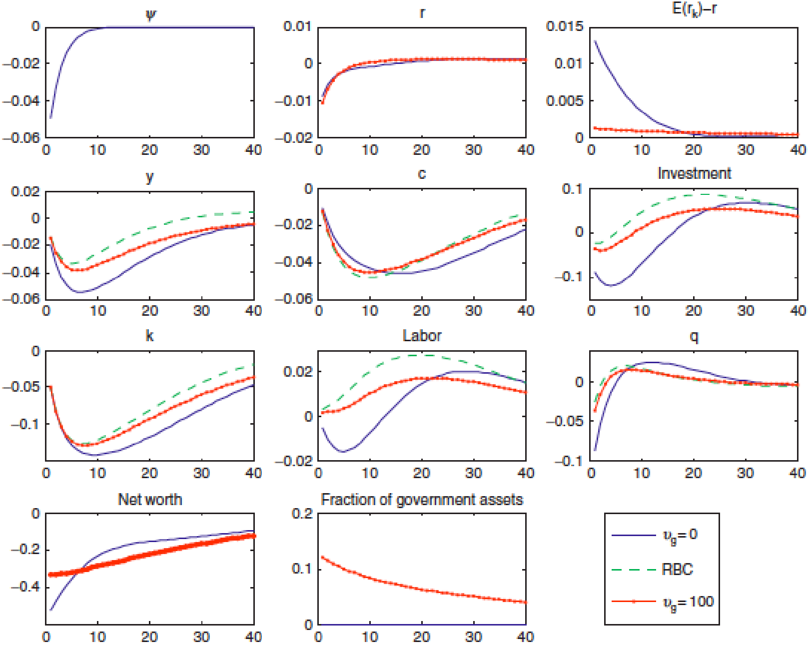
$$q_t^h s_t^h = n_t^h + n_t^g + b_t^h + d_t$$

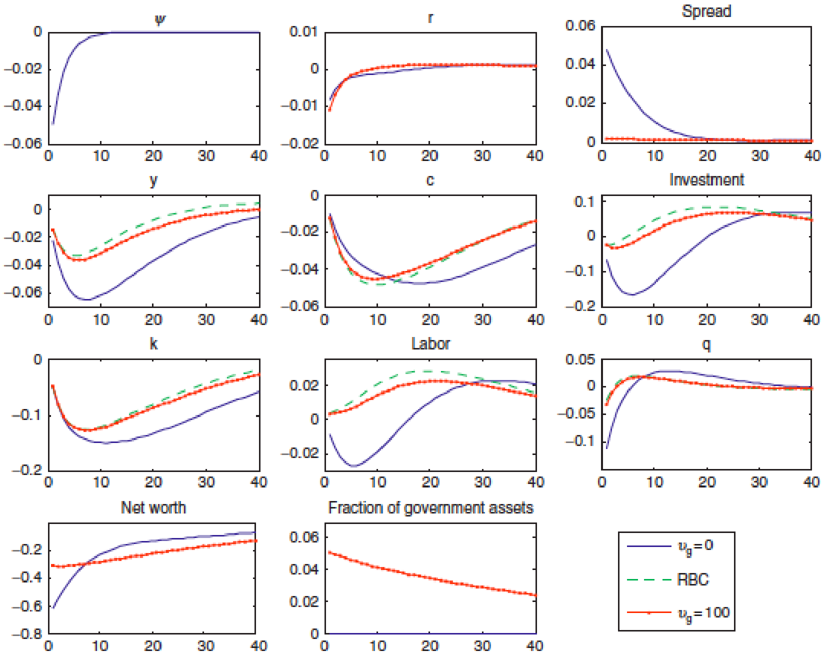
- Government must pay a premium.
- Why? Problems of issuing equity for banks in a crisis.

Households		
β	0.990	Discount rate
γ	0.500	Habit parameter
χ	5.584	Relative utility weight of labor
ε	0.100	Inverse Frisch elasticity of labor supply
Financial intermediaries		
π^i	0.250	Probability of new investment opportunities
θ	0.383	Fraction of assets divertable: perfect interbank market
	0.129	Fraction of assets divertable: imperfect interbank market
ξ	0.003	Transfer to entering bankers: perfect interbank market
	0.002	Transfer to entering bankers: imperfect interbank market
σ	0.972	Survival rate of the bankers
Intermediate good firms		
α	0.330	Effective capital share
δ	0.025	Steady-state depreciation rate
Capital producing firms		
$I f''/f'$	1.500	Inverse elasticity of net investment to the price of capital
Government		
$\frac{G}{Y}$	0.200	Steady-state proportion of government expenditures


ψ
r
$\times 10^{-3}$
$E(r_k)-r$
y
c
Investment
k
Labor
q
Net worth
Perfect interbank market
RBC


ψ
r
× 10⁻³
Spread
y
c
Investment
k
Labor
q
Net worth
Imperfect interbank market (π_i = 0.25)
RBC
Perfect interbank market


ψ
r
E(r_k)−r
y
c
Investment
k
Labor
q
Net worth
Fraction of government assets
υ_g = 0
RBC
υ_g = 100



ψ
r
Spread
y
c
Investment
k
Labor
q
Net worth
Fraction of government assets
$\upsilon_g=0$
RBC
$\upsilon_g=100$

Issues Ahead

- More detailed structure of bank capital.
- Different wholesale markets.
- Heterogeneity.
- Non-linearities.
- Optimal policy.