The Credit Channel of Monetary Policy II

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Plan for presentation

- Bernanke, Gertler Gilchrist model: Costly state verification

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- Partial equilibrium in capital market

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- General equilibrium model with financial accelerator. Macro effects. Empirical results

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- Partial equilibrium in capital market
- General equilibrium model with financial accelerator. Macro effects. Empirical results
- Using the central bank's balance sheet to stimulate the economy in a financial crisis

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- Look closely at partial equilibrium capital demand. Rest is more conventional.

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- Assume realized return R can be checked at a cost: If lender wants, she can check the return on the project. Will check return in order to get as much as possible in case of bankruptcy.
- If no bankruptcy, lender receives contracted return. If bankruptcy, part of return on project goes to cover "monitoring costs" or "bankruptcy cost".

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- $E(\omega^j) = 1$,i.i.d across time and across firms, c.d.f is $F(\omega)$. For lender, ω is observable only at a cost $\mu\omega^j R^k_{t+1} Q_t K_{t+1}$.

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- Return to capital for entrepreneur j is $\omega^j R_{t+1}^k$.Investment decision made before ω known.
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- $E(R_{t+1}^k)$ gross return to holding capital is determined in equilbrium. In partial equilibrium: assume constant.

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- To lender

$$\rho(\omega^j R^k_{t+1}, Z^j_{t+1}) =$$

$$\min[(1 - \mu)(\omega^j R^k_{t+1} Q_t K^j_{t+1} - Z^j_{t+1} B^j_{t+1}); Z^j_{t+1} B^j_{t+1}]$$

Contract designed gives lender zero profit in equilibrium

Define the critical $\omega^j = \overline{\omega}^j$ and Z^j_{t+1} where aggregate return exactly covers gross borrowing costs:

$$\overline{\omega}^j : \qquad \overline{\omega}^j R^k_{t+1} Q_t K^j_{t+1} = Z^j_{t+1} B^j_{t+1}$$

$=>F(\bar{\omega}^j)$ is probability of default. For which $\overline{\omega}^j$ and Z^j_{t+1} is lenders return equal to the risk-fre return on capital? Condition:

$$[1 - F(\overline{\omega}^j)] Z^j_{t+1} B^j_{t+1} + (1-\mu) \int_0^{\overline{\omega}^j} \omega R^k_{t+1} Q_t K^j_{t+1} dF(\omega) = R_{t+1} B^j_{t+1} \tag{3.4}$$

Will need weak assumption about the distribution of ω, $\quad F(\omega)$: Define hazard rate:

$$h(\omega) = \frac{d(F(\omega))}{1 - F(\omega)}$$

Will assume

$$\frac{\partial(\omega h(\omega))}{\partial(\omega)} > 0$$

Satisfied for most conventional distributions $F(\omega)$, including log-normal.

Substitute in expression for $Z^j_{t+1}B^j_{t+1}$ and for and for$B^j_{t+1} = Q_t K^j_{t+1} - N^j_{t+1}$, into previous equation and get condition only in terms of $\overline{\omega}^j$. Zero profit condition is now:

$$\left\{[1 - F(\overline{\omega}^j)]\overline{\omega}^j + (1-\mu)\int_0^{\overline{\omega}^j} \omega dF(\omega)\right\} R^k_{t+1} Q_t K^j_{t+1} = R_{t+1}(Q_t K^j_{t+1} - N^j_{t+1}) \tag{3.5}$$

Note that as $\overline{\omega}^j$ increases to an upper limit, as default probability $F(\overline{\omega}^j)$ goes to one, and lender must pay default cost with certainty. Assume R_{t+1} low enough to not make LHS increasing in $\overline{\omega}^j$ in equilibrium

Optimal contract designed by lender (cont.)

Expected payoff from loan contract concave and increasing in $\overline{\omega}^j$ for values below maximum $\overline{\omega}^j$;

$$\frac{d(LHS)}{d\overline{\omega}^j} = \left\{[1 - F(\overline{\omega}^j)] - \mu\bar{\omega}^j dF(\bar{\omega}^j)\right\} R^k_{t+1} Q_t K^j_{t+1} > 0$$

Two effects of $\overline{\omega}^j \uparrow$:

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- Optimal $\overline{\omega}^j$ also depends on R^k_{t+1} : Each realized R^k_{t+1}, goes with one $\overline{\omega}^j$. Borrower risk-neutral.

Behavior of borrower

Borrower is willing to agree to contract with $\overline{\omega}^j$ depending on realization of R^k_{t+1} (risk neutral). Cares about:

$$E\left\{\int_{\overline{\omega}^j}^{\infty} \omega R^k_{t+1} Q_t K^j_{t+1} dF(\omega) - (1 - F(\overline{\omega}^j))\overline{\omega}^j R^k_{t+1} Q_t K^j_{t+1}\right\} \qquad (3.6)$$

From 3.5 (zero profit condition) we know, for each R^k_{t+1},

$$\left\{[1 - F(\overline{\omega}^j)]\overline{\omega}^j\right\} R^k_{t+1} Q_t K^j_{t+1} =$$

$$R_{t+1}(Q_t K^j_{t+1} - N^j_{t+1}) - (1-\mu)\int_0^{\overline{\omega}^j} \omega dF(\omega) R^k_{t+1} Q_t K^j_{t+1}$$

Plug this into (3.6) , multiply by $E(R^k_{t+1})$ and divide by $U^{rk}_{t+1} \equiv \frac{R^k_{t+1}}{E(R^k_{t+1})} =>$

The equilibrium relationship between R^k and capital (K_{t+1}) purchased is found as

Optimal contract

max

$$E\left\{[1-\mu\int_{0}^{\overline{\omega}^j}\omega dF(\omega)]U^{rk}_{t+1}\right\}E(R^{\kappa}_{t+1})Q_tK^j_{t+1}-R_{t+1}(Q_tK^j_{t+1}-N^j_{t+1})$$

with respect to K_t and $\overline{\omega}^j$ (as a function of realized R^k_{t+1}), subject to set of constraints

$$\left\{[1-F(\overline{\omega}^j)]\overline{\omega}^j+(1-\mu)\int_0^{\overline{\omega}^j}\omega dF(\omega)\right\}R^k_{t+1}Q_tK^j_{t+1}= \qquad (3.5)$$

$$R_{t+1}(Q_tK^j_{t+1}-N^j_{t+1})$$

Exogenous: Price of capital, net worth brought in, aggregate risk-free return R_{t+1}, and distribution of risk.

Partial equilibrium in capital market

Define the return to capital:

$$s_t \equiv E\{R^k_{t+1}/R_{t+1}\}$$

Entrepreneur investing only if $s_t > 1$

Solving max-problem gives first order optimality condition:

$$Q_t K^j_{t+1} = \psi(s_t) N^j_{t+1} \quad (3.8)$$

In equilibrium, capital stock depends positively on net worth. $\psi(1) = 1$ means that with $E\{R^k_{t+1}/R_{t+1}\} = 1$, entrepreneurs will not borrow to invest. Given K_t determined from 3.8, constraint that gives lender zero expected return determines schedule for $\overline{\omega}^j$ (one $\overline{\omega}^j$ for each R^k_{t+1}).

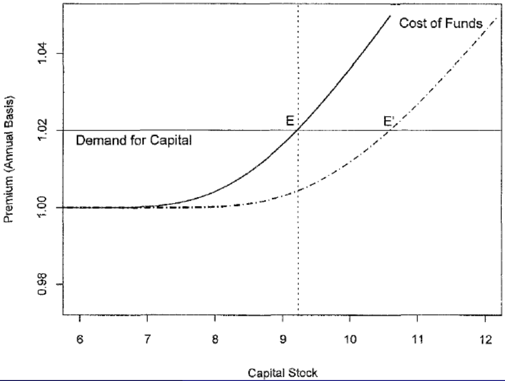
Partial equilibrium in capital market (cont)

$\psi'(\cdot) > 0$ means that increased return to capital reduces default probability and allows the firm to take on more debt. But size of firm cannot grow without limits: default costs rise as leverage rate increases.
In model last time: $\psi(s_t) = 1$, could only finance using full collateral or internal funds.
Here: aggregate over firms to get total demand for capital. Linear relationship (CRS)=>adding net worth gives total demand for capital.

Invert (3.8) to get expected excess return - the external finance premium, or supply of funds - as function of net worth:

$$\frac{E(R_{t+1}^k)}{R_{t+1}} = s(\frac{N_{t+1}^j}{Q_t K_{t+1}^j}), s'(\cdot) < 0$$

Expresses inverse relationship between external finance premium and amount of investment financed by own funds:



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- Entrepreneurs purchase capital each period for use next period. Idea: Use capital adjustment cost to get variable price of capital and hence variable N_{t+1}.
- Entrepreneurs hire workers, combine with K_t, CRS means aggregation easy,

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

Adjustment costs in capital stock

:

$$K_{t+1} = \Phi(\frac{I_t}{K_t})K_t + (1-\delta)K_t$$

=>

$$Q_t = [\Phi'(\frac{I_t}{K_t})]^{-1}$$

- Entrepreneurs sell output to retailers. X_t markup of retail goods over wholesale goods produced by entrepreneurs.

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- Gross return to capital (including price change)

$$E\{R^k_{t+1}\} = \{\frac{\frac{1}{X_{t+1}} \frac{\alpha Y_{t+1}}{K_{t+1}} + Q_{t+1}(1-\delta)}{Q_t}\}$$

Aggregate capital market equations/demand side:

Three main equations new in this paper:

$$\frac{E(R^k_{t+1})}{R_{t+1}} = s(\frac{N^j_{t+1}}{Q_t K^j_{t+1}}), s'(\cdot) < 0 \tag{4.5}$$

$$E\{R^k_{t+1}\} = \{\frac{\frac{1}{X_{t+1}}\frac{\alpha Y_{t+1}}{K_{t+1}} + Q_{t+1}(1-\delta)}{Q_t}\} \tag{4.4}$$

$$Q_t = [\Phi'(\frac{I_t}{K_t})]^{-1} \tag{4.3}$$

Log-linearize these to get (4.17)-(4.19) in paper, supply of external funds, marginal product of capital and link between asset prices and investment.

Supply side

Labour input:

$$L_t = H_t^{\Omega}(H_t^e)^{1-\Omega}$$

V_t =entrepreneural equity, W_t^e = entrepreneural wage, $\bar{\omega}_t$ is state contingent value of ω set in period 1. Aggregate net worth at end of period 1:

$$N_{t+1} = \gamma V_t + W_t^e$$

Only share γ of entrepreneurs from $t-1$ still active in period t. (and $C_t^e = (1-\gamma)V_t$)

$$V_t = R_t^k Q_{t-1} K_t - \left[R_t + \frac{\mu \int_0^{\bar{\omega}_t} \omega R_t^k Q_{t-1} K_t dF(\omega)}{Q_{t-1}K_t - N_{t-1}} \right] (Q_{t-1}K_t - N_{t-1})$$

External finance premium reflected in $\frac{\mu \int_0^{\bar{\omega}_t} \omega R_t^k Q_{t-1} K_t dF(\omega)}{Q_{t-1}K_t - N_{t-1}}$, which is ratio of default costs to quantity borrowed.

The dynamics of net worth

Demand for labour: From first order conditions in entrepreneurs profit-max problem (perfect competition, zero profits)

$$(1-\alpha)\Omega\frac{Y_t}{H_t} = X_t W_t \tag{4.11}$$

$$(1-\alpha)(1-\Omega)\frac{Y_t}{H_t^e} = X_t W_t^e \tag{4.12}$$

Combine $Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$, $N_{t+1} = \gamma V_t + W_t^e$, and

$(1-\alpha)(1-\Omega)\frac{Y_t}{H_t^e} = X_t W_t^e$ with

$$V_t = R_t^k Q_{t-1} K_t - \left[R_t + \frac{\mu \int_0^{\bar{\omega}_t} \omega R_t^k Q_{t-1} K_t dF(\omega)}{Q_{t-1} K_t - N_{t-1}} \right] (Q_{t-1} K_t - N_{t-1})$$

to get

$$\begin{aligned} N_{t+1} &= \gamma [R_t^k Q_{t-1} K_t - \left(R_t + \frac{\mu \int_0^{\bar{\omega}_t} \omega R_t^k Q_{t-1} K_t dF(\omega)}{Q_{t-1} K_t - N_{t-1}} \right) (Q_{t-1} K_t - N_{t-1} \quad (4 \\ &\quad + (1-\alpha)(1-\Omega) A_t K_t^{\alpha} H_t^{(1-\alpha)\Omega} \end{aligned}$$

Have now determined variation in net worth N_t, and we know how net worth influences cost of capital from

$$\frac{E(R^k_{t+1})}{R_{t+1}} = s(\frac{N^j_{t+1}}{Q_t K^j_{t+1}})$$

Now, need to determine variables kept exogenous so far: Relative price of wholesale goods $\frac{1}{X_t}$, R_t, and household real wage W_t. Need household, retail and government sector.

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- Households own retailers and get their profits.
- Two state variables: net worth and capital
- Monetary policy rule: $r_t = \rho r_{t-1}^n + \varsigma \pi_{t-1} + \varepsilon_t^{rn}$

(1) **Aggregate demand**

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}i_t + \frac{G}{Y}g_t + \frac{C^e}{Y}c_t^e + \cdots + \phi_t^y, \tag{4.14}$$

$$c_t = -r_{t+1} + E_t\{c_{t+1}\}, \tag{4.15}$$

$$c_t^e = n_{t+1} + \cdots + \phi_t^{c^e}, \tag{4.16}$$

$$E_t\{r_{t+1}^k\} - r_{t+1} = -\upsilon[n_{t+1} - (q_t + k_{t+1})], \tag{4.17}$$

$$r_{t+1}^k = (1-\epsilon)(y_{t+1} - k_{t+1} - x_{t+1}) + \epsilon q_{t+1} - q_t, \tag{4.18}$$

$$q_t = \varphi(i_t - k_t). \tag{4.19}$$

(2) **Aggregate Supply**

$$y_t = a_t + \alpha k_t + (1-\alpha)\Omega h_t, \tag{4.20}$$

$$y_t - h_t - x_t - c_t = \eta^{-1} h_t, \tag{4.21}$$

$$\pi_t = E_{t-1}\{\kappa(-x_t) + \beta\pi_{t+1}\}. \tag{4.22}$$

(3) **Evolution of State Variables**

$$k_{t+1} = \delta i_t + (1-\delta)k_t, \tag{4.23}$$

$$n_{t+1} = \frac{\gamma RK}{N}(r_t^k - r_t) + r_t + n_t + \cdots \phi_t^n. \tag{4.24}$$

(4) **Monetary Policy Rule and Shock Processes**

$$r_t^n = \rho r_{t-1}^n + \varsigma \pi_{t-1} + \varepsilon_t^{rn}, \tag{4.25}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g, \tag{4.26}$$

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \tag{4.27}$$

with

$$\phi_t^y \equiv \frac{DK}{Y}\left[\log\left(\mu \int_0^{\bar{\omega}_t} \omega \,\mathrm{d}F(\omega) R_t^k Q_{t-1} K_t / DK\right)\right],$$

$$D \equiv \mu \int_0^{\bar{\omega}} \omega \,\mathrm{d}F(\omega) R^k,$$

$$\phi_t^{c^e} = \log\left(\frac{1 - C_{t+1}^e / N_{t+1}}{1 - C^e/N}\right),$$

$$\phi_t^n \equiv \frac{(R^k/R - 1)K}{N}(r_t^k + q_{t-1} + k_t) + \frac{(1-\alpha)(1-\Omega)(Y/X)}{N} y_t - x_t,$$

$$\nu \equiv \frac{\psi(R^k/R)}{\psi'(R^k/R)}, \quad \epsilon \equiv \frac{1-\delta}{(1-\delta) + \alpha Y/(XK)},$$

$$\varphi \equiv \frac{(\Phi(I/K)^{-1})'}{(\Phi(I/K)^{-1})''}, \quad \kappa \equiv \left(\frac{1-\theta}{\theta}\right)(1 - \theta\beta).$$

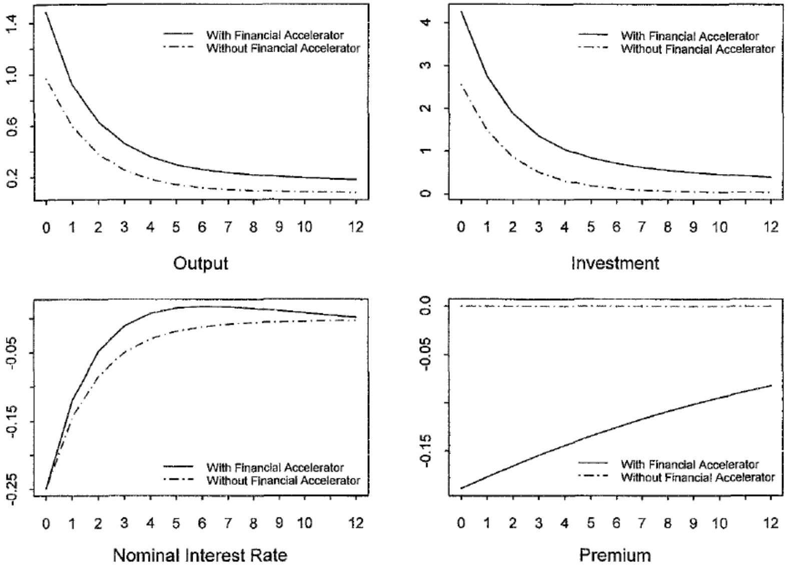

Fig. 3. Monetary shock – no investment delay. All panels: time horizon in quarters.

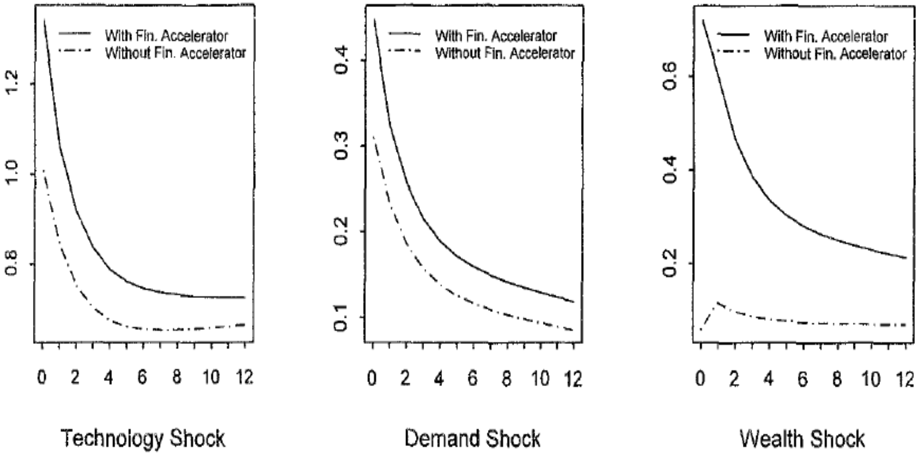

Fig. 4. Output response – alternative shocks. All panels: time horizon in quarters.

Measures taken by some central banks recently seem to involve more than just interest rate decision

- Terminology

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Government (G), Central bank (CB) and private sector including banks (P).

Government (G)

R_G	B_P
L_G	B_{CB}

Private (P)

B_P	F
R_P	L_G

Central Bank(CB)

B_{CB}	R_G
F	R_P
V	Own funds

- The government holds reserves R_G in central bank, lends to the private sector L_G, issues bonds that are held by the private sector (B_P) and held by the central bank (B_{CB}).

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- The central bank holds government bonds (B_{CB}) and loans to the private sector (F) and foreign reserves (V).The central bank creates liquidity R_G and R_P held by the government and the private sector.

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- This would be quantitative easing to *the extent that the balance sheet of the CB increase*s, but it would also change the riskiness of the asset side, and hence also involve "qualitative easing"

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- "Printing money" (buying government assets directly from government) is illegal in most developed countries.

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- buy private sector assets in exchange for short term private assets.
- It could also be purchase of other private sector assets, financed by central bank reserves R_p. In that case this would simultaneously increase the balance sheet of the central bank, and hence involve quantitative easing as well.

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- The mechanism could be a financial accelerator that improves banks funding conditions when their balance sheets improve (net risk-adjusted worth goes up). The improved funding may increase lending, and alleviate credit rationing and hence help monetary policy to be effective.

Fed and UK measures

- The measures emphasised by Bernanke on January 13th, are "qualitative easing", it involves buying risky private sector assets, or guaranteeing those. The financing of those determine whether it also is quantitative easing: If they are financed by central bank reserves R_p, they are also quantitative easing (central bank balance sheet increases), if they are financed by selling governement bonds to private sector, they are pure qualitative easing.

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- Could finance the APF by issuing R_p instead of issuing government papers. This would be combination of qualitative and quantitative easing.