# Monetary Economics

## Lecture 19: financial market frictions, part one

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# This lecture

- Macroeconomics with financial market frictions, part one

- Agency costs. Costly state verification. Amplification and propagation of shocks.

  ◇ Brunnermeier, Eisenbach and Sannikov "Macroeconomics with financial frictions: a survey," NBER working paper 2012

    section 1, sections 2.1–2.2

  ◇ Bernanke, Gertler and Gilchrist "The financial accelerator in a quantitative business cycle framework," *Handbook of Macroeconomics*, 1999

Readings available from the LMS

# This lecture

**1-** Static 'costly state verification' model of financial contracting

– Townsend (1979 JET), Gale and Hellwig (1985, ReStud)

**2-** Embedded in real business cycle model

– Carlstrom and Fuerst (1997 AER)

**3-** Embedded in a new Keynesian model with sticky prices

– Bernanke, Gertler and Gilchrist (1999)

# Overview

- Costly monitoring (financial friction)
- Nontrivial financial structure, Modigiliani-Miller does not apply
- Shocks amplified, propagated through borrower *net worth $n$*
- Depending on setup, may be further amplified or dampened by fluctuations in *price of capital $q$*
- Additional effects with sticky prices (e.g., unanticipated deflation increases real debt, reduces net worth)

# Model

- Risk neutral borrowers (entrepreneurs)
  - ex ante identical, endowed with initial net worth $n$
  - has *project* technology, transforms cons. goods into capital goods

$$i \text{ consumption goods } \mapsto \omega i \text{ capital goods}$$

with idiosyncratic risk $\omega$ realized after investment $i$ has been made

$$\omega \sim \text{ IID } \Phi(\omega) \equiv \text{Prob}[\omega' \leq \omega] \text{ with } \mathbb{E}[\omega] = 1$$

  - the ex post realization of $\omega$ is *private information*

- Risk neutral lender, competitive

- For now, net worth $n$ and relative price of capital $q$ taken as given

# Entrepreneurs

- Borrow $i - n$ units of consumption, repay $R(i - n)$ units of capital
- Invest in project, delivers $\omega i$ units of capital
- Depending on $\omega$, may be infeasible to repay loan. In default if

$$\omega i \leq R(i - n) \qquad \Leftrightarrow \qquad \omega < \bar{\omega} \equiv R\frac{i - n}{i}$$

- If in default, only repay $\omega i$ (i.e., there is *limited liability*)

# Private information and monitoring

- Entrepreneur knows $\omega$ ex post, has incentive to claim bad returns — i.e., repay only $\omega i$, not $R(i-n)$ — and keep more for self

- Lender can monitor project at cost $\mu i$, reducing project payoff to

$$(\omega - \mu)i$$

- Optimal financial structure minimizes these monitoring costs

# Optimal contract: overview

- Can be specified in terms of $(R, i)$ or equivalently $(\bar{\omega}, i)$

$$\bar{\omega} \equiv R\frac{i-n}{i}$$

- Along the equilibrium path ...

... loan $i - n$, entrepreneur invests $i$, stochastic outcome $\omega i$, then if

$\omega \geq \bar{\omega}$ entrepreneur repays $R(i-n) = \bar{\omega}i$ and keeps net proceeds

$$\omega i - R(i-n) = (\omega - \bar{\omega})i$$

$\omega < \bar{\omega}$ entrepreneur defaults and gets zero, lender monitors and gets

$$(\omega - \mu)i$$

# Optimal contract: intuition

- No incentive for entrepreneur to lie
  - in non-default states, payment is $\bar{\omega}i$ independent of $\omega$
  - in default states there is monitoring
- Agency costs are minimized
  - giving everything to lender in default state minimizes probability of default, hence minimizes monitoring costs (losses due to $\mu$)

# Entrepreneur's expected payoff

- In units of consumption

$$q \int_{\bar{\omega}}^{\infty} (\omega - \bar{\omega}) i \, d\Phi(\omega)$$

(get nothing if default, repay $\bar{\omega} i$ otherwise)

- Write this as

$$q f(\bar{\omega}) i, \qquad f(x) \equiv \int_{x}^{\infty} (\omega - x) \, d\Phi(\omega)$$

and note $f(0) = 1$, $f(\infty) = 0$ and $f'(x) = -(1 - \Phi(x)) < 0$

# Lender's expected payoff

- In units of consumption

$$q\Big[\int_0^{\bar\omega}(\omega-\mu)i\,d\Phi(\omega)+\int_{\bar\omega}^{\infty}\bar\omega i\,d\Phi(\omega)\Big]$$

(monitor if $\omega<\bar\omega$, repaid $\bar\omega i$ otherwise)

- Write this as

$$qg(\bar\omega)i, \qquad g(x)\equiv\int_0^x(\omega-\mu)\,d\Phi(\omega)+x(1-\Phi(x))$$

and note $g(0)=0$, $g(\infty)=1-\mu$

- From now on, write $x\equiv\bar\omega$ to streamline notation

# Project shares

- Note sum of these shares

$$f(x) + g(x) = 1 - \mu\Phi(x)$$

- Expected monitoring cost (deadweight loss)

$$\mu\Phi(x)$$

# Optimal contract

- Project scale $i$ and monitoring threshold $x \equiv \bar{\omega}$ that
- Maximizes entrepreneur's expected payoff

$$qf(x)i \geq n$$

- Subject to lender's break-even condition

$$qg(x)i \geq i - n$$

# Optimal contract

- Lagrangian for this problem

$$L = qf(x)i + \lambda\big[qg(x)i - i + n\big]$$

(ignoring entrepreneur's participation constraint)

- First order conditions for interior solutions

$$\begin{aligned} i: &\qquad qf(x) + \lambda\big[qg(x) - 1\big] = 0 \\ x: &\qquad qf'(x)i + \lambda\big[qg'(x)i\big] = 0 \end{aligned}$$

- So we can write multiplier as

$$\lambda = \frac{\partial L}{\partial n} = -\frac{f'(x)}{g'(x)}$$

# Optimal contract

- Eliminating $\lambda$ and rearranging

$$g(x) - g'(x)\frac{f(x)}{f'(x)} = \frac{1}{q}$$

which characterizes monitoring threshold $x(q)$, is independent of $n$

- Then from lender's break-even condition

$$i = \frac{1}{1 - qg(x(q))}n \equiv \psi(q)n$$

(this is the entrepreneur's *leverage ratio*)

- Implied repayment rate, in units of consumption goods

$$qR = q\frac{xi}{i-n} = \frac{x(q)}{g(x(q))}$$

($qR - 1$ is the net *external finance premium*, compensates lender for monitoring)

# Leverage and expected return on equity

- Leverage ratio

$$i = \frac{1}{1 - qg(x(q))} n \equiv \psi(q) n$$

- So the entrepreneur's expected payoff is

$$\frac{qf(x(q))}{1 - qg(x(q))} n \equiv \rho(q) n \geq n$$

- The coefficient $\rho(q)$ is the entrepreneur's expected *return on internal funds* (return on equity)

- For given $q$, a high leverage ratio increases the return on equity. From the entrepreneur's participation constraint, $\rho(q) \geq 1$

- For given $x$, a high price of capital $q$ increases expected payoff both directly and via leverage (ability to borrow against given $n$)

# Carlstrom/Fuerst

- Now to embed this in general equilibrium, make $n, q$ endogenous

- Real business cycle model with two types of agents

  - entrepreneurs (borrowers)
  - households (ultimate source of funds for loans)

- Households acquire capital through competitive financial intermediaries (*capital mutual funds*, CMFs) that effectively pool idiosyncratic project risk and that lend to entrepreneurs

- In other words, households exposed to aggregate risk but not idiosyncratic risk

# Carlstrom/Fuerst

- **Households:** (fraction $1-\eta$ of the population), maximize

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t, h_t) \right\}, \qquad 0 < \beta < 1$$

subject to budget constraint

$$c_t + q_t[k_{t+1} - (1-\delta)k_t] \leq w_t h_t + r_t k_t$$

($q_t$ to CMF delivers one unit of capital for sure at end of period)

- First order conditions for the household

$$-\frac{U_{h,t}}{U_{c,t}} = w_t$$

and

$$1 = \mathbb{E}_t \left\{ \beta \frac{U_{c,t+1}}{U_{c,t}} \frac{r_{t+1} + q_{t+1}(1-\delta)}{q_t} \right\}$$

# Carlstrom/Fuerst

- **Entrepreneurs:** (fraction $\eta$ of the population), maximize

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} (\gamma\beta)^t c_{e,t} \right\}, \qquad 0 < \gamma\beta < \beta$$

(risk neutral and more impatient than households)

- For entrepreneurs that do not go bankrupt

$$c_{e,t} + q_t k_{e,t+1} \leq f(x_t) i_t = \frac{f(x_t)}{1 - q_t g(x_t)} n_t \equiv \rho_t n_t$$

- Net worth at beginning of period

$$n_t = w_{e,t} + [r_t + q_t(1-\delta)] k_{e,t}$$

- Euler equation for entrepreneur

$$1 = \mathbb{E}_t \left\{ \gamma\beta \frac{r_{t+1} + q_{t+1}(1-\delta)}{q_t} \rho_{t+1} \right\}$$

# Aggregates

- Aggregate capital, consumption, investment, and labor

$$
\begin{aligned}
K_t &= \eta k_{e,t} + (1-\eta)k_t \\
C_t &= \eta c_{e,t} + (1-\eta)c_t \\
I_t &= \eta i_t \\
H_t &= ((1-\eta)h_t)^{1-\varsigma} h_{e,t}^{\varsigma}, \qquad h_{e,t} = \eta \text{ and } \varsigma \approx 0
\end{aligned}
$$

(household and entrepreneurial labor not perfect substitutes)

- Capital accumulation

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

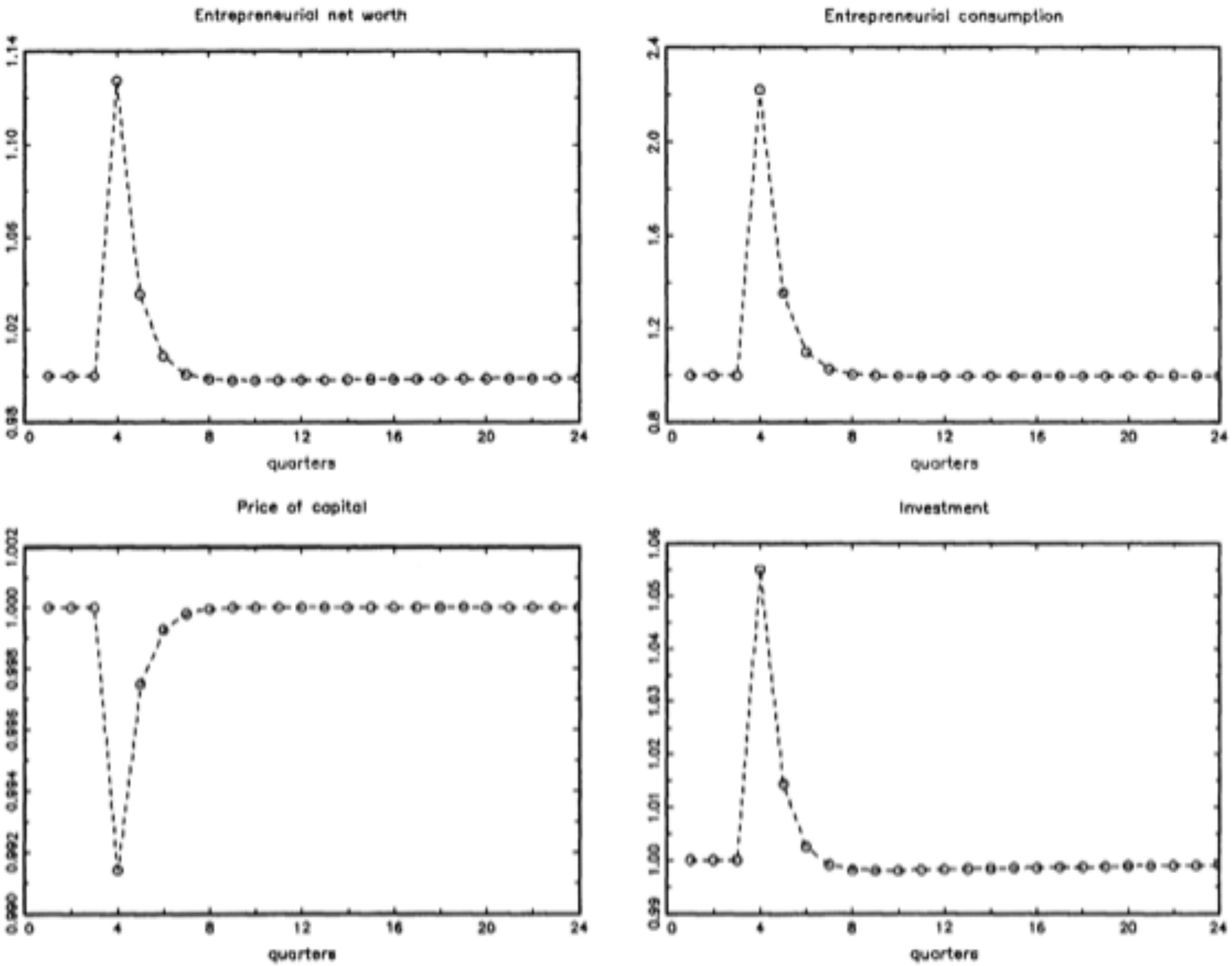
- Goods market clearing

$$C_t + I_t = Y_t = A_t F(K_t, H_t)$$

# Intuition

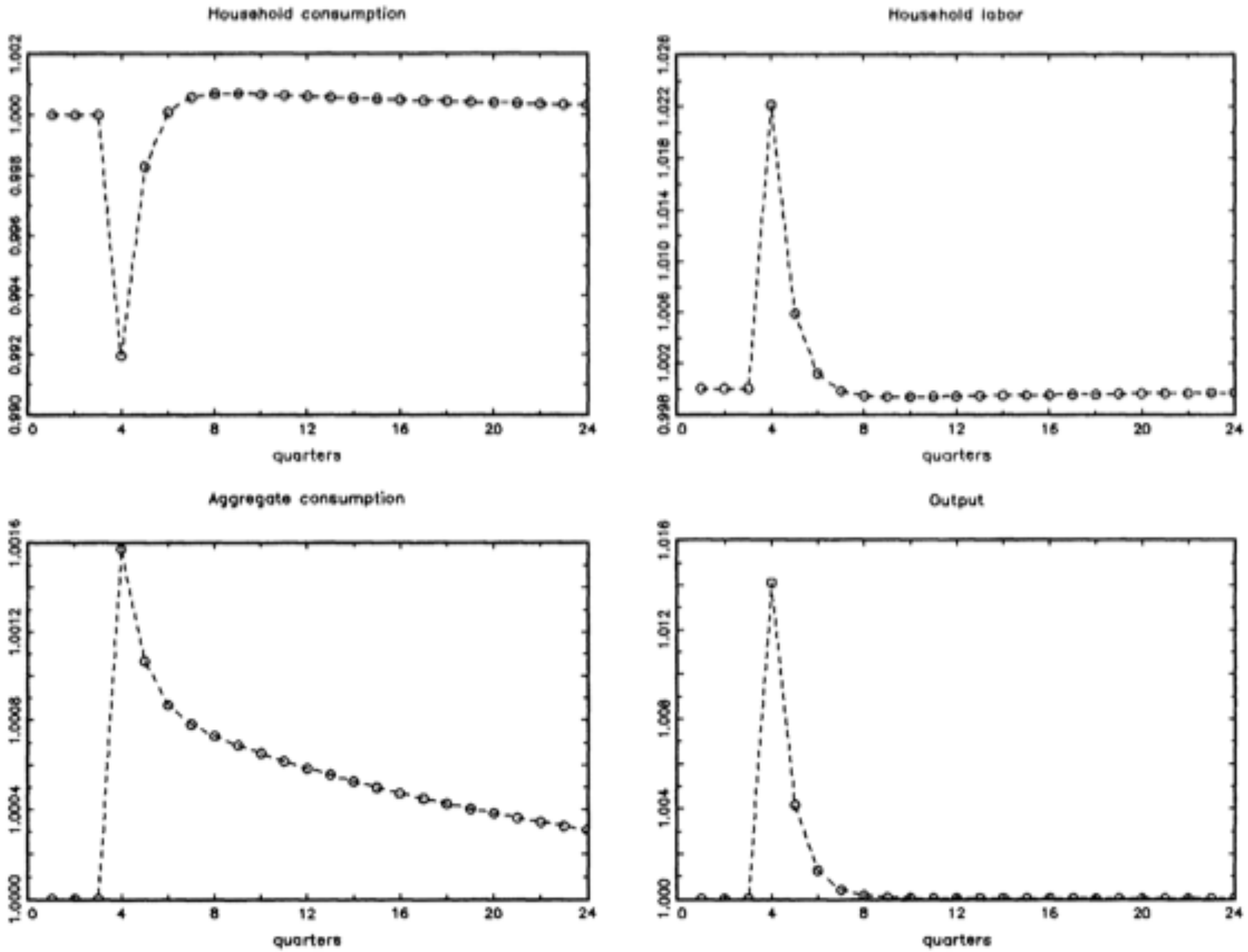
- Boom (positive productivity shock $A_t$)
  - increases net worth $n_t$, this in turn
  - reduces financial friction (reduces reliance on external finance)
  - increases investment scale, increases supply of capital goods
  - increases output, increases future net worth $n_{t+1}$ (propagation)
  - further amplified or dampened by changes in price of capital $q_t$
- To disentangle effects, first consider a pure shock to $n_t$ that leaves aggregate productivity unchanged

# Transitory shock to net worth



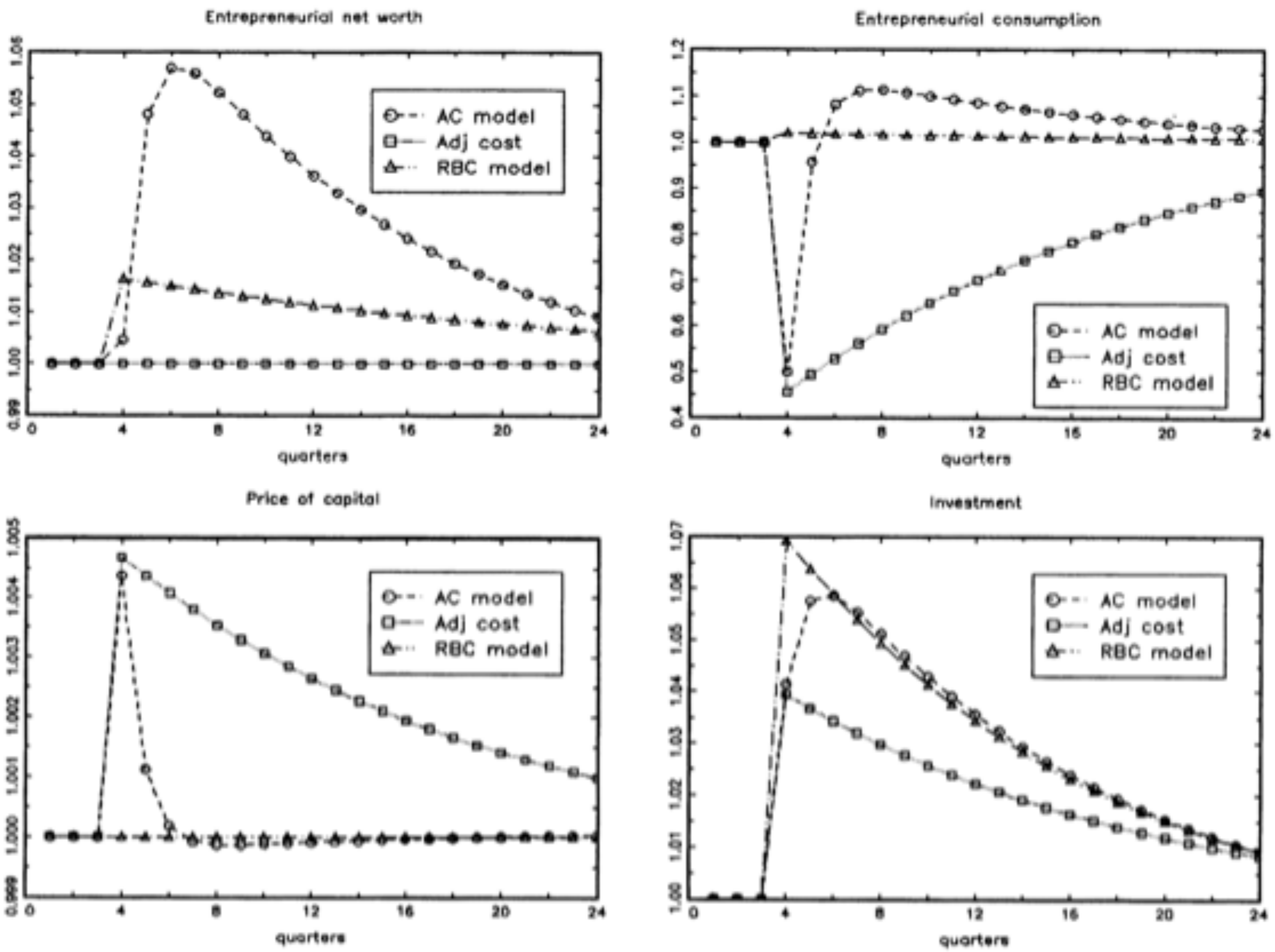

Unanticipated 0.1% redistribution of capital from households to entrepreneurs. Large 13% increase in entrepreneurial net worth. Lowers reliance on external finance, increases supply of capital (downward pressure on price of capital $q_t$.)

# Transitory shock to net worth, cont



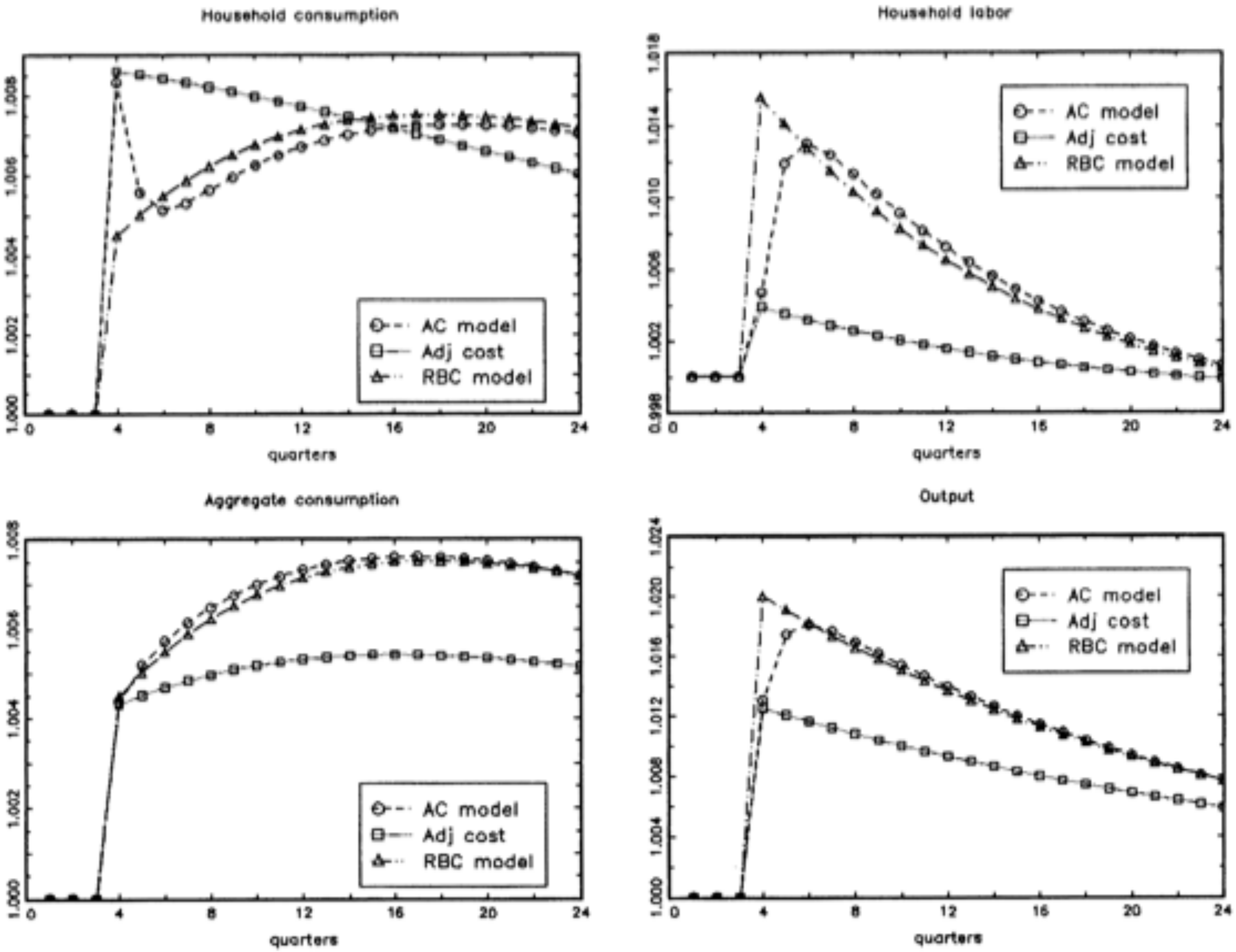

Unanticipated 0.1% redistribution of capital from households to entrepreneurs. Household consumption falls, but aggregate consumption rises. Households supply more labor. Output rises.

# Persistent productivity shock




Unanticipated 0.1% shock to aggregate productivity with AR(1) coefficient 0.95. Compares agency cost model, benchmark RBC model ($\mu = 0$), and RBC model with capital adjustment costs (but without net worth channel).

# Persistent productivity shock, cont




Net worth increases a lot as $q_t$ increases return on internal funds $\rho_t$. Household consumption dampened to meet investment demand. Households supply more labor. Hump-shaped output response but not significantly amplified.

# Discussion

- Productivity shock increases net worth $n_t$ but also increases demand for capital

- Increase in net worth also shifts out capital supply, dampens effect on $q_t$ and hence *undermines* amplification properties

- Bernanke, Gertler and Gilchrist's alternative setup prevents this

# CF and BGG setups compared

**CF:**

- Agency costs only affect producers of investment goods (who produce capital directly from final output)
- Output produced by separate firms that do not face agency costs
- Changes in net worth work primarily through supply price of capital. When net worth is high, more capital supply and $q_t$ dampened, which mitigates boom

**BGG:**

- Agency costs apply to producers of output who *own the whole capital stock*
- Increase in $q_t$ create more amplification — the *financial accelerator*

# Bernanke, Gertler and Gilchrist

- Sketch

  – entrepreneurs produce goods using capital and labor

  – buying $k_{t+1}$ requires borrowing

  $$q_t k_{t+1} - n_t$$

  subject to agency cost frictions

  – investment (creation of new capital) by separate sector

  – sticky prices (at final 'retail' level), nominal shocks have real effects

# Bernanke, Gertler and Gilchrist

- Investment sector, adjustment costs

$$K_{t+1} - K_t = (\Xi(I_t/K_t) - \delta)K_t$$

where $\Xi(\cdot)$ is strictly increasing and strictly concave with $\Xi(0) = 0$

- Produce new capital using final output $I_t$ as 'materials', sold at price $q_t$ to entrepreneurs who use it in production

- First order condition

$$q_t\Xi'(I_t/K_t) = 1$$

Price of capital increases with investment demand

# Bernanke, Gertler and Gilchrist

- From agency cost problem, entrepreneur's leverage given by

$$q_t k_{t+1} = \psi(s_t) n_t$$

(similar to before), where $\psi'(s_t) > 0$ and where

$$s_t \equiv \frac{\mathbb{E}_t[R_{t+1}^k]}{R_t}$$

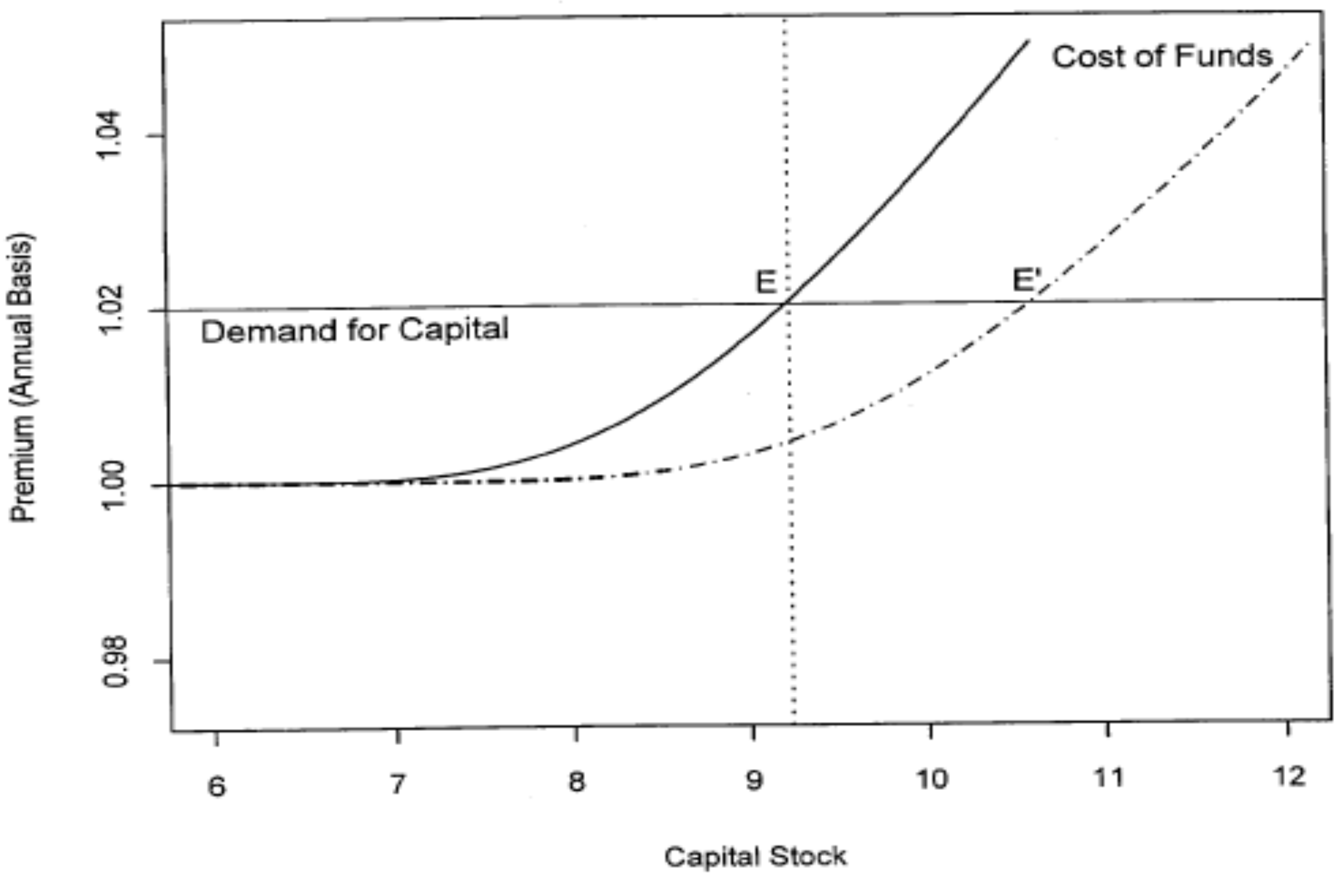
is the *premium* of the aggregate return on capital over the opportunity cost of funds (paid to obtain external finance)

- In aggregate

$$\frac{\mathbb{E}_t[R_{t+1}^k]}{R_t} = s(\frac{q_t K_{t+1}}{N_t}), \qquad s(\cdot) = \psi^{-1}(\cdot)$$

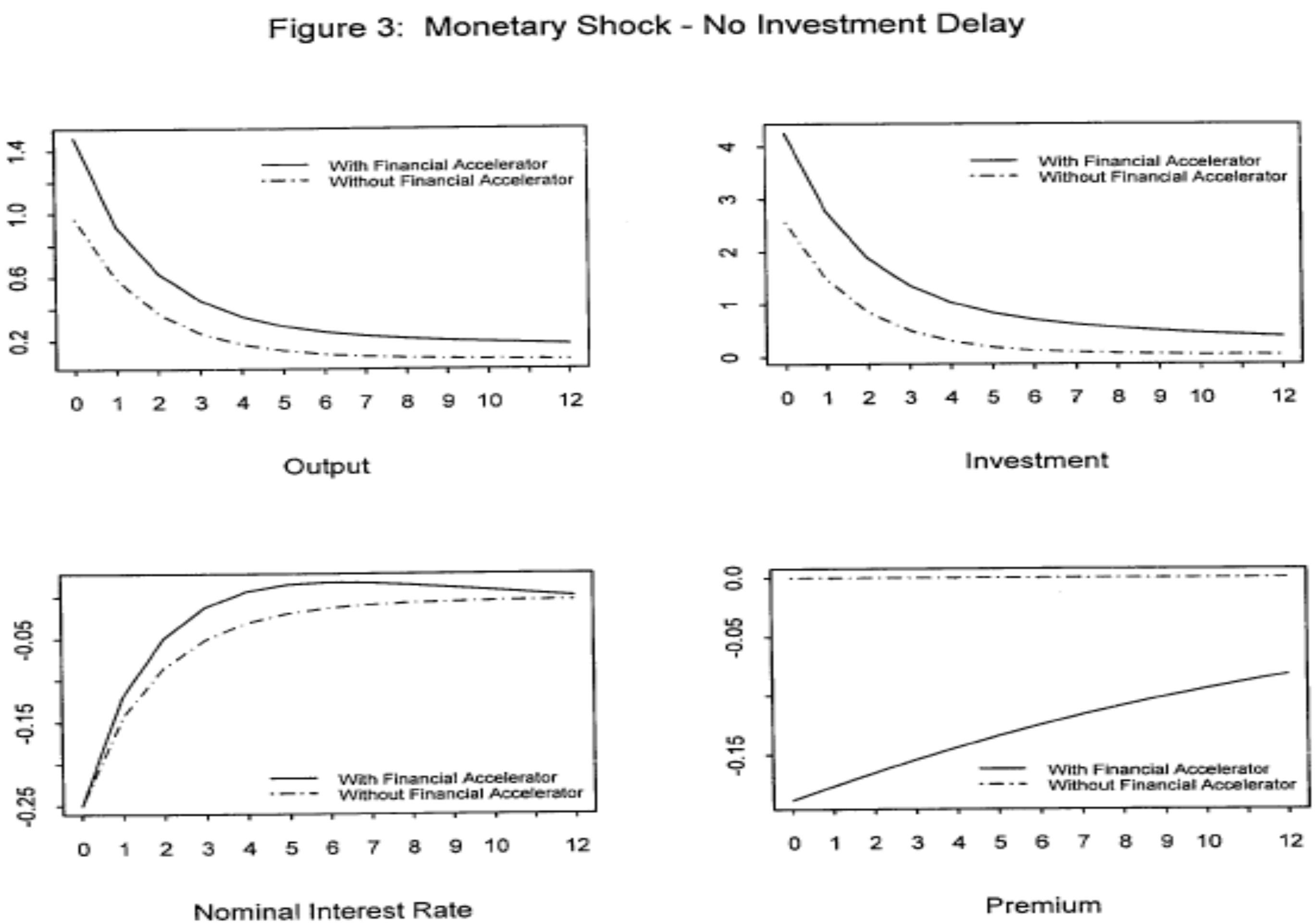
(increases in aggregate leverage put upward pressure on premium)

Figure 1: The Effect of an Increase in Net Worth



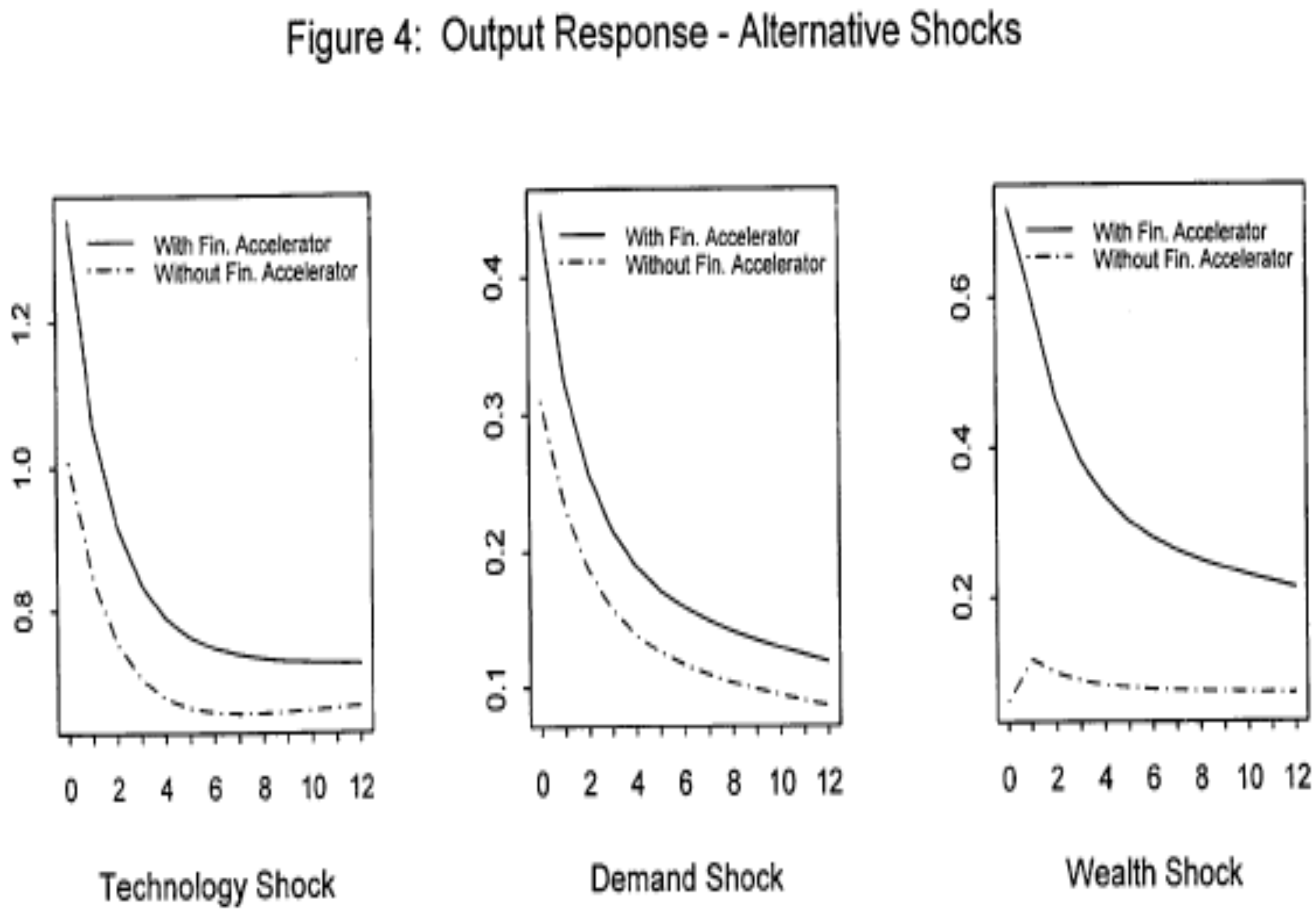

Leverage $qK = \psi(s)N$ Steady state premium is $s = 2\%$, desired $qK$ corresponding to steady state leverage ratio of 2 (point $E$). An increase in net worth $N$ by 15% reduces premium at old level of capital. Capacity can be expanded to $E'$.

# Expansionary monetary policy shock




Unexpected 25 bp decline in nominal interest rate. ‘Without financial accelerator’ means keeping premium fixed at steady state 2% rather than letting it respond endogenously. Output and investment responses are amplified when premium is endogenous. Expansionary monetary policy reduces the premium.

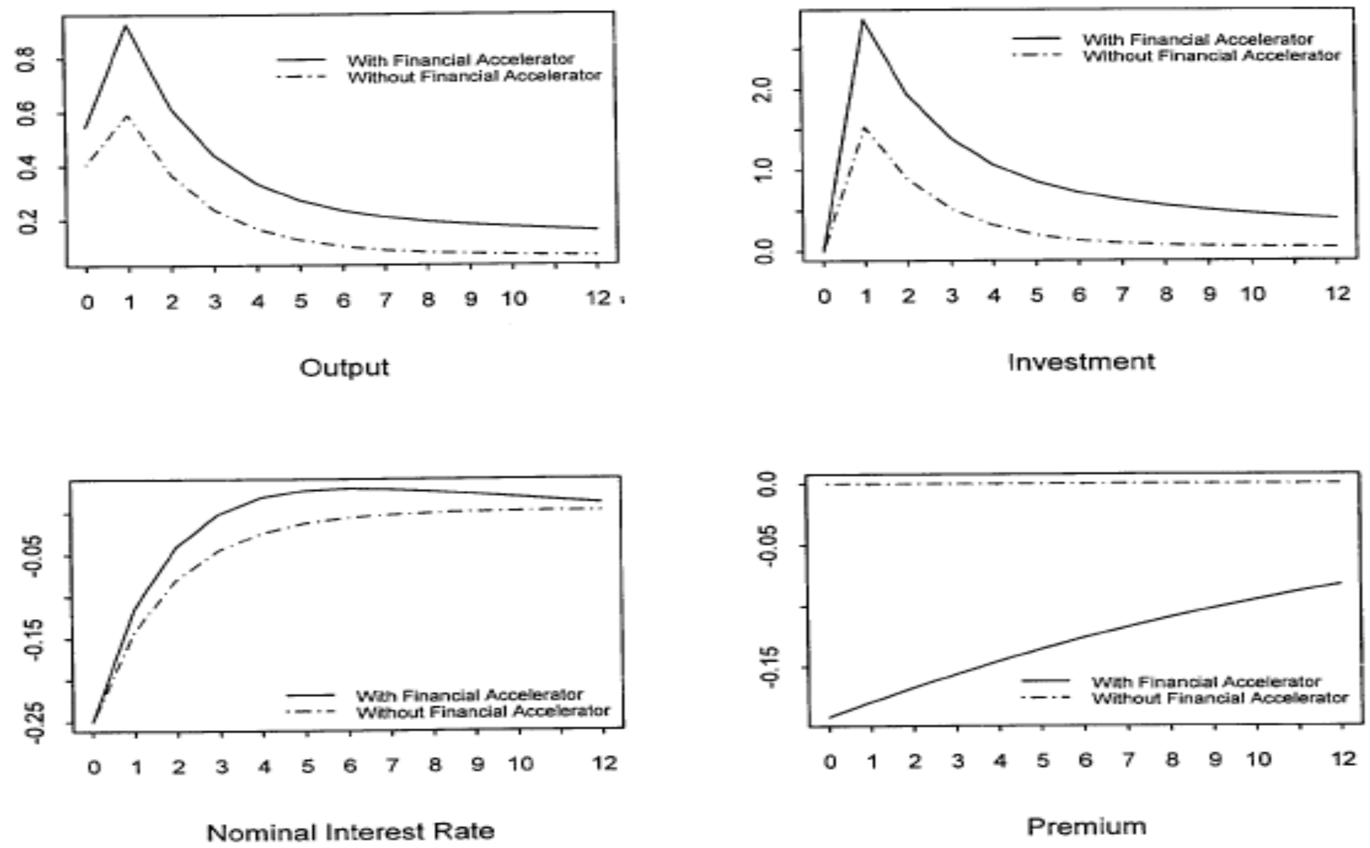
# Alternative shocks




Productivity, government purchases, and entrepreneurial wealth shocks. The latter is a redistribution of wealth from households to entrepreneurs.

# Investment delays

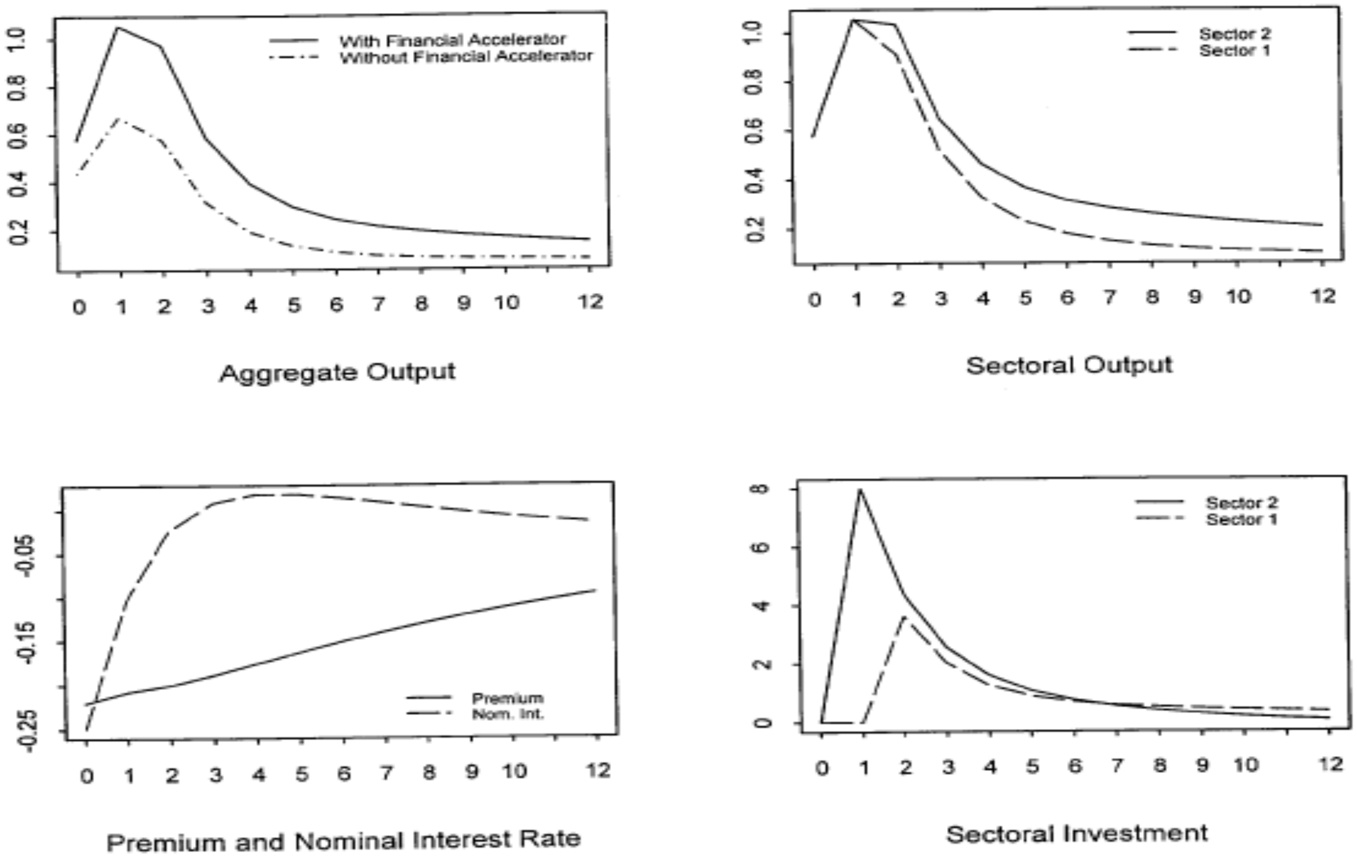
Figure 5: Monetary Shock - One Period Investment Delay




Here investment must be planned one quarter in advance. Impulse responses to expansionary monetary policy shock. Note asset prices (i.e., the external finance premium) jumps immediately even though quantities respond with one-period delay.

# Large firms and small firms

Figure 6: Monetary Shock - Multisector Model with Investment Delays




Heterogeneous firms where large firms (sector 1) have lower steady state external finance premium. Also investment delays as above. Shock is again expansionary 25bp unexpected cut in nominal interest rates. Note small firms (sector 2) are more sensitive to premium in that investment responds more strongly than for large firms.

# Next lecture

- Macroeconomics with financial market frictions, part two
- Endogenous risk etc
  - Brunnermeier, Eisenbach and Sannikov "Macroeconomics with financial frictions: a survey," NBER working paper 2012

    section 1, section 2.3
  - Brunnermeier and Sannikov "A macroeconomic model with a financial sector," *American Economic Review*, 2014

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