

# The Effects of Monetary Policy, and Other, Announcements in Dynamic General Equilibrium

Chao Gu

Han Han

Randall Wright

University of Missouri

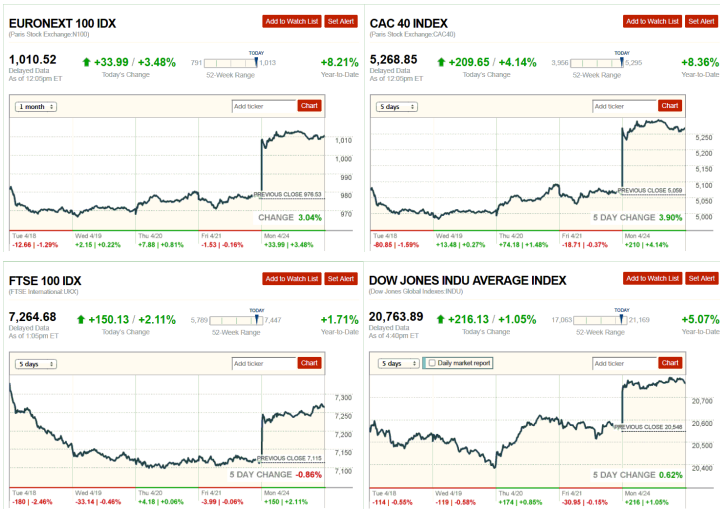
Peking University

UW-Madison & FRB Chicago

# Introduction

- ▶ Our goal: To study how Wall St and Main St react to news at  $t_0$  about events at  $t_1 > t_0$ .
- ▶ Events can be changes in, eg, productivity or monetary policy:
  - ▶ “Bernanke Speaks and Shares Tumble.” (NY Times)
  - ▶ “The view that monetary policy is, at least in part, about *managing expectations* is by now standard in both academia and central banking circles.” (Blinder et al JEL)
- ▶ Paper is not only about high freq financial data, but consider:

# Motivating Evidence 1



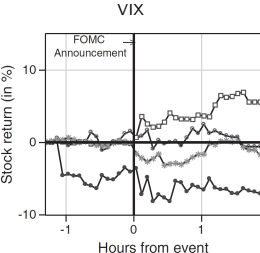
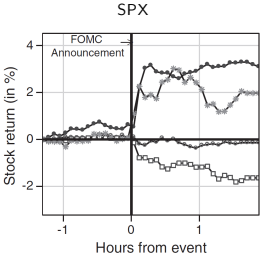
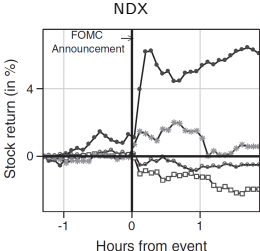
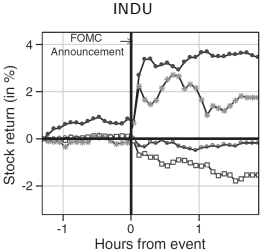
# Motivating Evidence 2

—●— 18 Apr 2001

—○— 19 Mar 2002

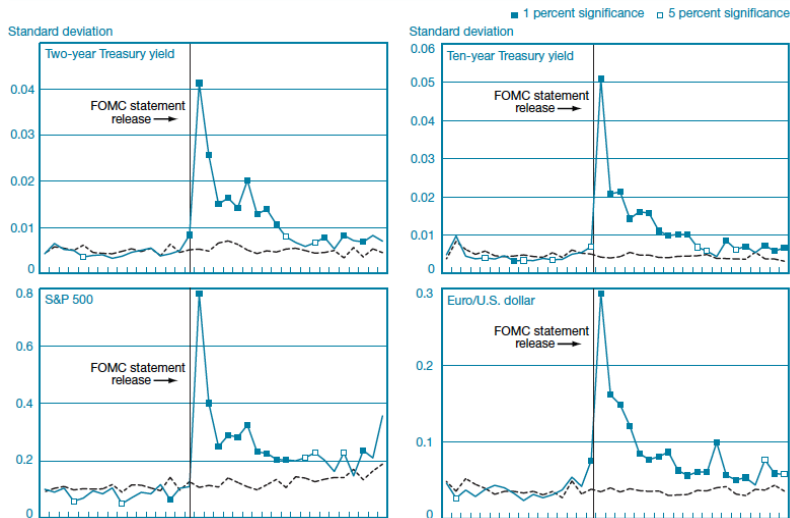
—□— 28 Jan 2004

—\*— 18 Mar 2009



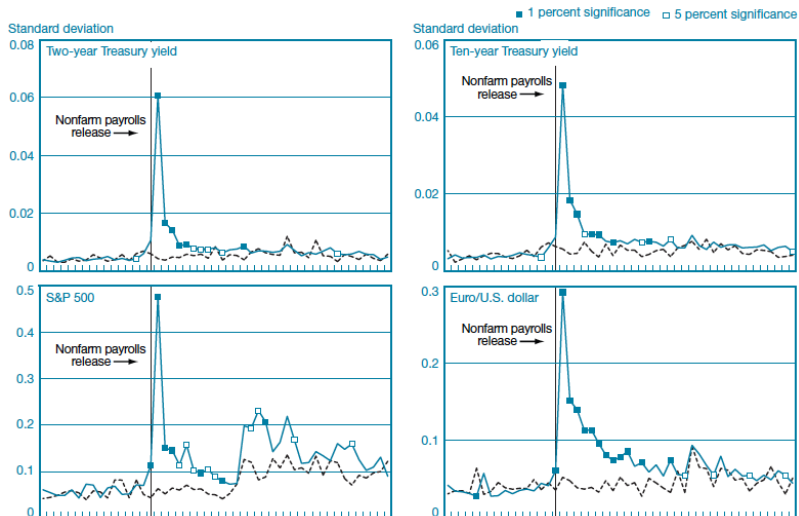
Stock market reactions to Fed announcements (Rosa 2011)

# Motivating Facts 3



Impact of Fed announcements on volatility (Rosa 2013)

# Motivating Facts 4



Impact of real news on volatility (Rosa 2013)

# Main Results 1

- ▶ Construct transitions from  $t_0$  about events at  $t_1$  in economies where liquidity plays a role – eg, money, credit, both etc.
  - ▶ liquidity considerations introduce more nonlinearity into GE
- ▶ News  $\Rightarrow$  intricate dynamics whether the event is neutral (eg, cash injection) or not (eg, productivity shock).
  - ▶ this is not standard endogenous dynamics: *we focus on the unique equilibrium that is stationary for given parameters*
- ▶ Money shocks have real effects iff anticipated – opposite to the classical view of Friedman, Lucas, Sargent-Wallace etc.

## Main Results 2

- ▶ Policy announcements induce rather than reduce volatility, the *opposite* of conventional wisdom on forward guidance:
  - ▶ Blinder et al: “central bank talk increases the predictability of central bank actions, which should in turn reduce volatility in financial markets.”
  - ▶ Matsumoto et al: “providing more information about future fundamentals would reduce asset price volatility.”
- ▶ We provide counterexamples.



## Main Results 3

- ▶ Idea: It is optimal to announce good events in advance and keep bad ones secret, as in Andolfatto et al or Dang et al
- ▶ We provide counterexamples.
  - ▶ eg, it can be good to announce a monetary injection (ie, a debasement) in advance
- ▶ But trying to exploit this by policy is impractical.
  - ▶ results are highly dependent on timing and parameter values

# Literature

- ▶ Central bank communication
- ▶ Recent studies of news effects
- ▶ The New Monetarist theoretical framework
  - ▶ key feature: asynchronicity between receipts and expenditure  
⇒ need for payment instrument, eg money or credit.
  - ▶ makes the framework ideal for studying issues related to liquidity and monetary policy

# Standard Model

- ▶ Continuum of infinitely-lived buyers  $b$  and sellers  $s$ .
  - ▶ can be households, firms or financial institutions
- ▶ Each  $t = 1, 2, \dots$  two markets convene sequentially:
  - ▶ DM:  $s$  sells and  $b$  buys  $q_t$
  - ▶ CM: trade  $(\mathbf{x}_t, \ell_t)$ , adjust assets and settle debts
- ▶ Payoffs:  $U^b(\mathbf{x}_t, \ell_t) + u(q_t)$  &  $U^s(\mathbf{x}_t, \ell_t) - c(q_t)$
- ▶ Policy: for now, changes in money supply  $\mu_t$ .

# Pure Monetary Economy: CM

- ▶ Assume  $U^b(\mathbf{x}_t, \ell_t) = U(x_t) - \ell_t$  with  $x_t$  numeraire. Then

$$W_t(m_t) = \max_{x_t, \ell_t, \hat{m}_{t+1}} \{U(x_t) - \ell_t + \beta V_{t+1}(\hat{m}_{t+1})\}$$
$$\text{st } x_t = \ell_t + \phi_t m_t - \phi_t \hat{m}_{t+1} + \tau_t$$

- ▶ Lemma:  $\hat{m}_{t+1} \perp m_t$  and  $W'_t(m_t) = \phi_t$ .
- ▶ FOC for money demand:

$$\phi_t = \beta V'_{t+1}(\hat{m}_{t+1})$$

# Pure Monetary Economy: DM

- ▶  $b$  and  $s$  trade  $(d_t, q_t)$  st  $d_t \leq m_t$ .
- ▶ To reduce notation let  $c(q_t) = q_t$ .
- ▶ Paper uses  $\phi_t d_t = v(q_t)$ , a generic pricing mechanism; here we use  $v(q_t) = q_t$ .
- ▶ If  $\alpha = \text{prob}(b \text{ trades})$  then

$$V_t(\hat{m}_t) = \alpha [u(q_t) + W(\hat{m}_t - d_t)] + (1 - \alpha) W_t(\hat{m}_t)$$

# Pure Monetary Equilibrium

- ▶ Now FOC for  $\hat{m}_{t+1}$  leads to

$$z_t = f_{t+1}(z_{t+1}) \equiv \frac{\beta z_{t+1} [1 + \alpha \lambda(z_{t+1})]}{1 + \mu_{t+1}}$$

where  $z = \phi m$  and  $\lambda(z)$  is the *liquidity premium*,

$$\lambda(z) \equiv \begin{cases} u'(z) - 1 & \text{if } z < q^* \\ 0 & \text{otherwise} \end{cases}$$

- ▶ Prop: for fixed parameters  $\exists!$  SME  $\bar{z} = f(\bar{z}) > 0$ .

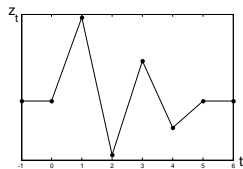
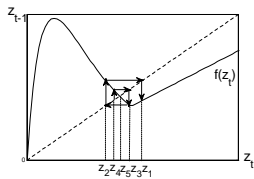
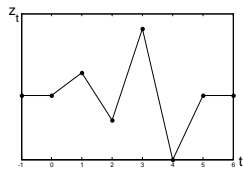
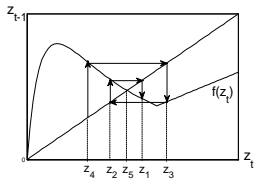
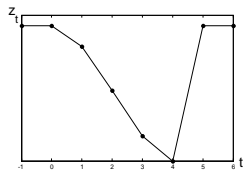
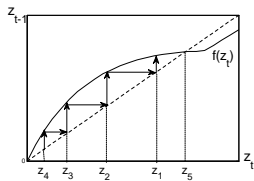
## Beyond Rational Expectations

- ▶ Initially agents expect  $\mu_t = \bar{\mu} \forall t$ .
- ▶ At  $t = t_0$  they get news that at  $T > t_0$  there will be a one-time  $M$  injection:  $\mu_T > \bar{\mu}$ .
- ▶ Given we return to SME after the injection,  $z_T = \bar{z}$  and

$$z_{T-1} = f_T(z_T) = \frac{(1 + \bar{\mu})\bar{z}}{1 + \mu_T} < \bar{z}.$$

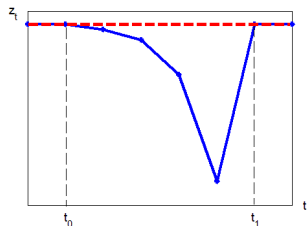
- ▶  $z_{t-1} = f_t(z_t)$  with  $\mu_t = \bar{\mu}$  for  $t < T \Rightarrow$  unique transition.
- ▶ But it can look *very different* depending on parameters.

# Transitions

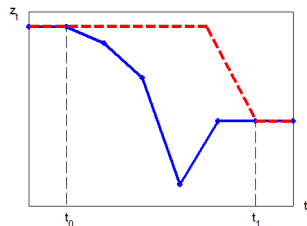




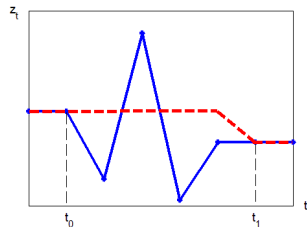
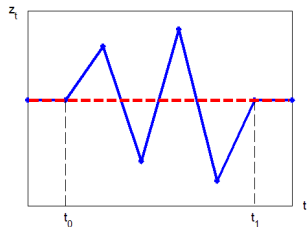
# Transparency or Opacity: To Tell the Truth?



neutral change



nonneutral change



# Not So Far Beyond Rational Expectations

- ▶ Above agents believe  $\mu_t = \bar{\mu} \forall t$  until  $t_0$ , then learn  $\mu_T \neq \bar{\mu}$ .
- ▶ But  $\mu_T$  is not in the support of their beliefs.
- ▶ Now suppose they believe  $\mu_t \in \mathcal{S}$  is a stochastic process.
- ▶ If  $z_t = \hat{m}_t \mathbb{E}_t \phi_t$  the generalized system is:

$$z_{t-1} = f_t(z_t) = \beta z_t [1 + \alpha L(z_t)] \mathbb{E}_t \left( \frac{1}{1 + \mu_t} \right).$$

- ▶ Now news at  $t_0$  can be  $\mu_T \in \mathcal{S}_T \subset \mathcal{S}$  or a change in CDF.
- ▶ For anything that changes  $\mathbb{E}_T \left( \frac{1}{1 + \mu_T} \right)$  the same results hold.

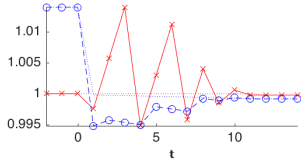
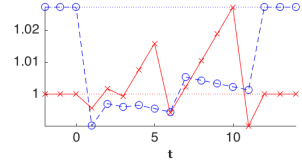
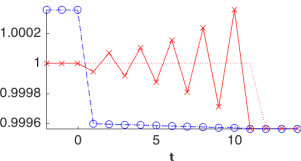
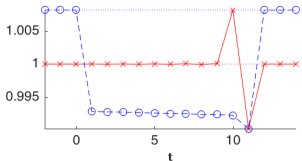
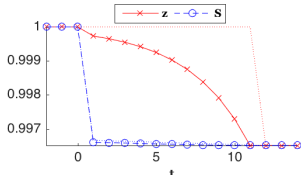
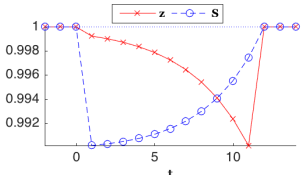
# Numerical Work

- ▶ This is not a calibration but we use realistic parameters.
- ▶ Functional forms:

$$c(q) = \frac{q^{1+\sigma}}{1+\sigma} \text{ and } u(q) = A \frac{(q+b)^{1-\gamma} - b^{1-\gamma}}{1-\gamma}$$

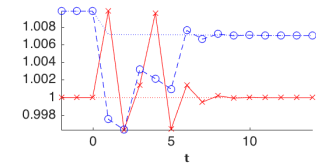
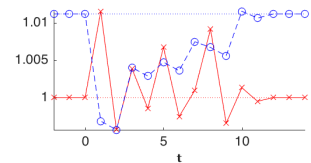
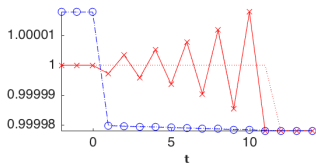
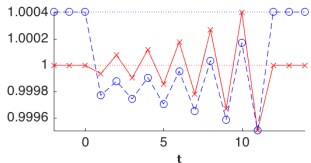
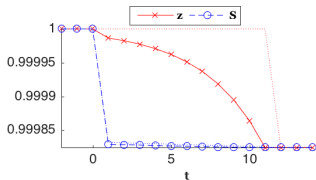
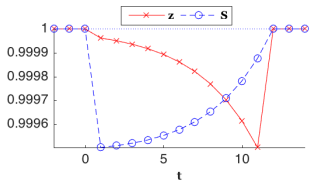
- ▶ Default values:  $\sigma = 0$ ,  $A = 1$ ,  $b = 0.1$ ,  $\gamma = 0.5, 4, 8$ .
- ▶ Monthly model with  $\beta$  and  $\mu$  set to deliver annual real interest and inflation rates of 5%.
- ▶ Typical news: 1% change in variable announced  $T = 12$  (months) in advance.

# Benchmark Model



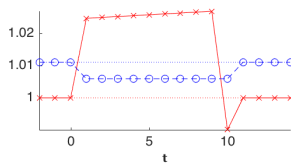
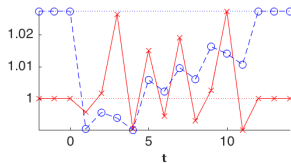
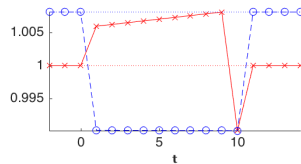
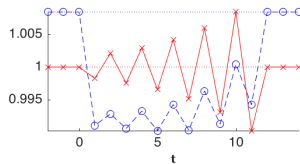
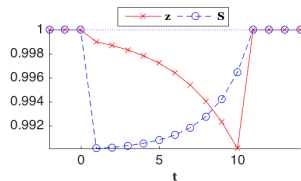
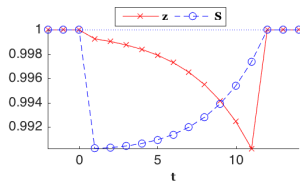
Temporary (left) and Permanent (right) Increase in  $\mu$

# Effects of Smaller Changes



Temporary (left) and permanent (right) increase in  $\mu$

# Effects of Different Period Length



Temporary Increase in  $\mu$ , Quarterly (left) and Daily (right)

# Lesson 1

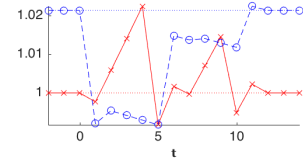
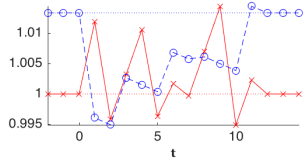
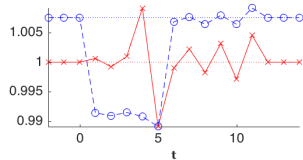
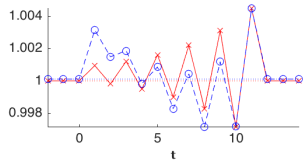
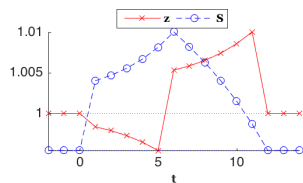
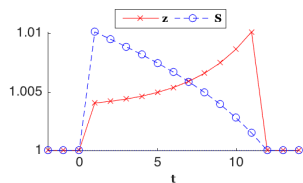
- ▶ Monetary policy announcements can induce intricate dynamics before implementation.
- ▶ This is true whether the policy is neutral or nonneutral.
- ▶ For longer periods or smaller changes, news is more likely to generate oscillations.
- ▶ News-induced volatility can improve welfare, but it depends critically on the timing and parameter values.

## Application: Quantitative Easing (Waller)

- ▶ Given QE increased the money supply *a lot*, why didn't prices go up?
- ▶ Feldstein dubs this *The Inflation Puzzle*.
- ▶ This is ostensibly a stark violation of the quantity theory
- ▶ Consider an announcement at  $t = 0$  that  $M$  will be injected at  $T_1 > 0$  and extracted at  $T_2 > T_1$ .

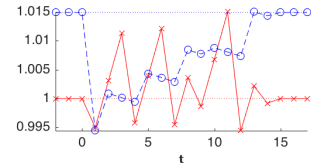
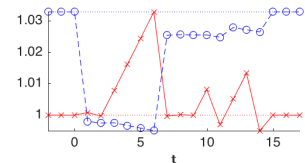
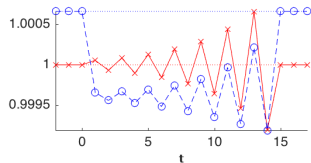
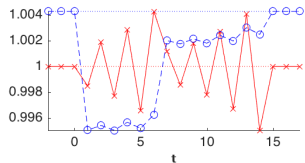
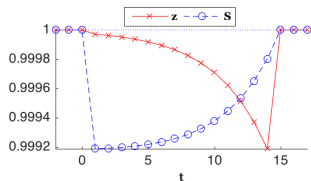
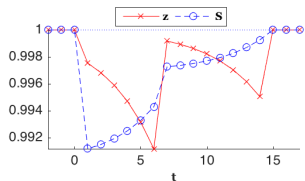


# Effect of Quantitative Easing



Quantitative Easing with  $T_1 = 0$  (left) and  $T_1 > 0$  (right)

# More General Multiple Announcements



Staggered News (left) and Random News (right)

## Lesson 2

- ▶ Multiple and staggered announcements can induce even more intricate dynamics.
- ▶ Apropos QE, news of future decreases in  $M$  temper the effects of current increases
- ▶ Beneficial effects of QE arise mainly from decreasing  $M$  in the LR, not increasing it in the SR.
- ▶ It is hard to see the quantity equation (neutrality) in the data even when it is true by construction.

## Real assets (Geromichalos et al RED)

- ▶ Replace cash with a Lucas tree with dividend  $\rho_t$ .
- ▶ Let  $\chi \leq 1$  be pledgeability (Kiyotaki-Moore) parameter.
- ▶ Liquidity is now  $z_t = \chi(\psi_t + \rho_t)$  and the dynamic system is:

$$z_{t-1} = \beta z_t [1 + \alpha \chi \lambda(z_t)] + \chi \rho_{t-1}$$

## Money and Asset (Lester et al RES)

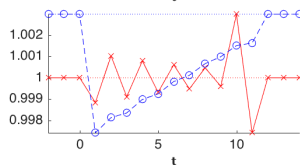
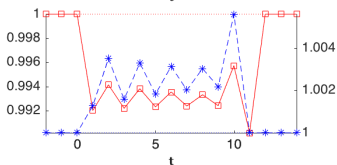
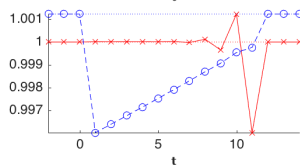
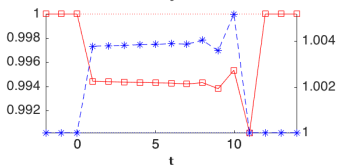
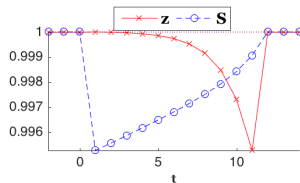
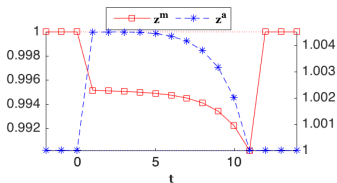
- ▶ Combine fiat and real assets to get a two-dimensional system:

$$z_{t-1}^m = \frac{\beta z_t^m}{1 + \mu_t} [1 + \alpha_m \lambda(z_t^m) + \alpha_b \lambda(z_t)]$$

$$z_{t-1}^a = \beta z_t^a [1 + \chi \alpha_b \lambda(z_t)] + \chi \rho_{t-1}$$

where  $z_t^m = \phi_t M_t$ ,  $z_t^a = \chi(\psi_t + \rho_t)$ , and  $z_t = z_t^m + z_t^a$ .

# Effects of Money on Equity Markets



Money-and-Asset Economy, Temporary Increase in  $\mu$

## Lesson 3

- ▶ Without money, when liquidity is scarce productivity news can induce intricate dynamics in stock prices and output.
- ▶ With money, productivity or monetary policy news can induce intricate dynamics in stock prices and output.
- ▶ This is true whether policy is neutral or nonneutral.
- ▶ And whether assets are used as payment instruments (Kiyotaki- Wright) or as collateral for credit (Kiyotaki-Moore).

## Two Monies (Zhang JIE)

- ▶ Motivated by news monetary policy affecting exchange rates, consider two fiat currencies:

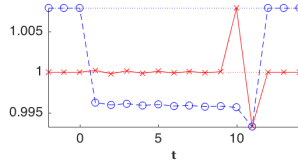
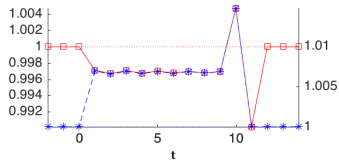
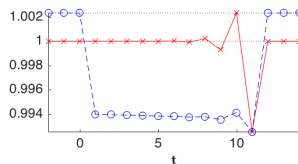
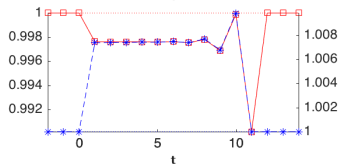
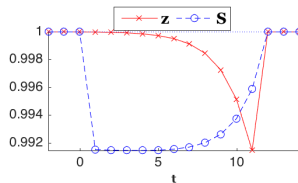
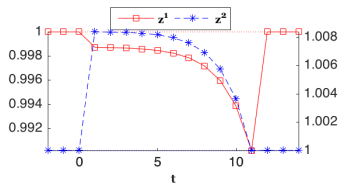
$$z_{t-1}^1 = \frac{\beta z_t^1}{1 + \mu_t^1} [1 + \alpha_1 \lambda(z_t^1) + \alpha_b \lambda(z_t)]$$

$$z_{t-1}^2 = \frac{\beta z_t^2}{1 + \mu_t^2} [1 + \alpha_2 \lambda(z_t^2) + \alpha_b \lambda(z_t)]$$

- ▶ Special cases like  $\alpha_b = 0$  are OK, but  $\alpha_1 = \alpha_2 = 0 \Rightarrow$  really only one money (Kareken-Wallace)



# Effect of Money on Exchange Rates



Two-Money Economy, Temporary Increase in  $\mu^1$

## Lesson 4

- ▶ News about monetary policy or real factors in one country can induce dynamics in both countries' prices, output, interest and exchange rates.
- ▶ This is true whether policy is neutral or nonneutral.

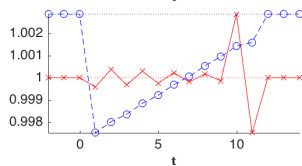
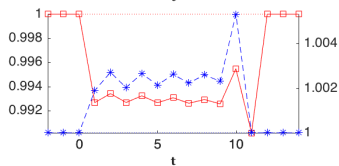
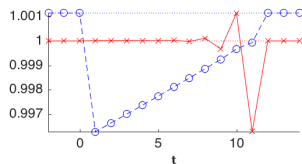
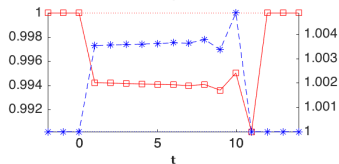
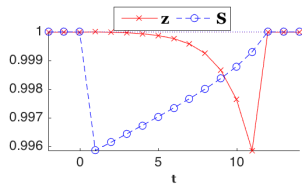
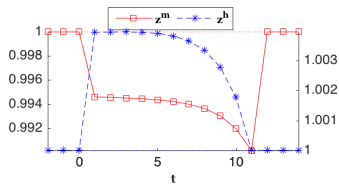
## Money and Housing (He et al RED)

- ▶ Housing enters budget eqn and utility function  $\Rightarrow$  more nonlinearity.
- ▶ Home equity can be used as collateral in DM.
- ▶ With money and housing,

$$z_{t-1}^h = \beta z_t^h [1 + \chi_h \alpha_b \lambda(z_t)] + \beta \chi_h U_2(x_t, h_t) h_t$$

$$z_{t-1}^m = \frac{\beta z_t^m [1 + \alpha_m \lambda(z_t^m) + \alpha_b \lambda(z_t^b)]}{1 + \mu_t}$$

# Effects of Money on Housing



Housing-and-Money Economy, Temporary Increase in  $\mu$

## Lesson 5

- ▶ When liquidity is scarce and housing can be used as collateral, monetary policy or productivity news can induce intricate dynamics in prices.
- ▶ In particular, news can induce booms, crashes and cycles in house prices with associated dynamics in output.
- ▶ This is true whether policy is neutral or nonneutral.

# Kehoe-Levine Credit (Gu et al JPE, RES)

- ▶ Debtor consumes  $X$  and produces  $Y$  in subperiod 1, invests  $Y$  for return  $RY$ .
- ▶ Creditor produces  $X$  in subperiod 1 and consumes  $RY$  in subperiod 2.
  - ▶ Debtor & creditor payoffs:  $u(X) - Y$  &  $RY - c(X)$ .
- ▶ Repayment constraint

$$\beta V_{t+1} \geq \Lambda_t R_t Y_t + (1 - \pi_t) \beta V_{t+1} \implies R_t Y_t \leq D_t$$

where  $\Lambda_t$  is payoff from opportunistic default.

# Equilibrium

- ▶ Mechanism determines  $(X_t, Y_t)$  given  $D_t$ .
- ▶ Endogenous debt limit follows

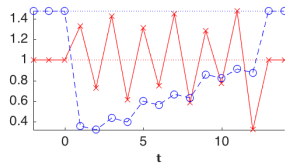
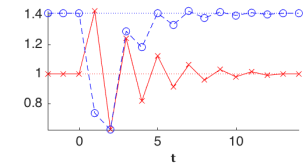
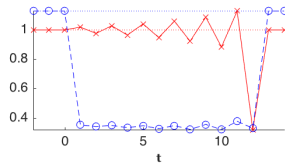
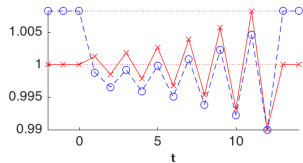
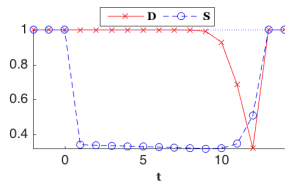
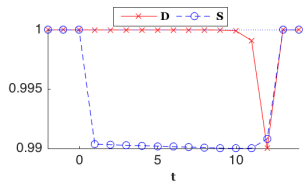
$$D_t = f(D_{t+1}) \equiv \beta \frac{\alpha \pi_t}{\Lambda_t} S(D_{t+1}) + \beta \frac{\pi_t}{\pi_{t+1}} D_{t+1},$$

where

$$S(D_t) = \begin{cases} u \circ X(D_t) - D_t/R_t & \text{if } D_t < p_t^* \\ u(X_t^*) - p_t^*/R_t & \text{if } D_t \geq p_t^* \end{cases}$$

- ▶ The dynamic  $f(\cdot)$  looks just like the monetary model!

# Effects of Changes in Credit Condition



Credit Economy, Temporary Decrease in  $\pi$  (left) and  $R$  (right)



# Money and Credit (Gu et al Econometrica)

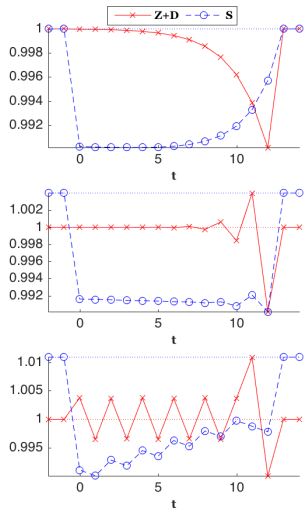
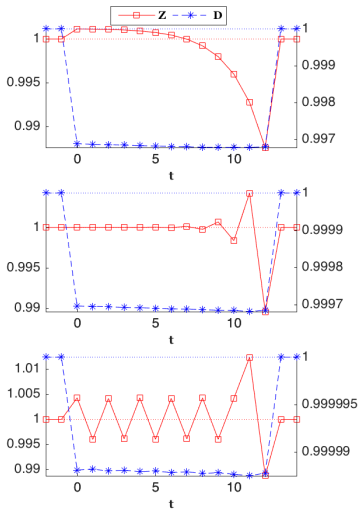
- ▶ Combine money and credit to study their interactions.

$$z_{t-1} = \frac{\beta z_t [1 + \alpha \lambda (D_t + z_t)]}{1 + \mu_t}$$

$$D_{t-1} + \frac{\pi}{\Lambda} z_{t-1} = \beta \frac{\alpha \pi}{\Lambda} S (D_t + z_t) + \beta D_t + \beta \frac{\pi}{\Lambda} z_t$$

- ▶ Thm: A permanent change in  $D$  is neutral in monetary equil.
- ▶ But news about  $D$  is nonneutral, just like news about  $M$  is nonneutral.

# Effects of Money on Credit Conditions



Money-and-Credit Economy, Temporary Increase in  $\mu$

## Lesson 6

- ▶ Without money, news about changes in credit conditions can induce intricate dynamics in debt limits, the amount and terms of lending, prices and output.
- ▶ With money, news about monetary policy or credit conditions can induce dynamics in all these variables, whether or not policy is neutral.
- ▶ Bad news about money tends to tighten credit, while bad news about credit conditions tends to boost the value of money.

# Interest Rate Targeting

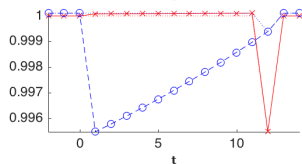
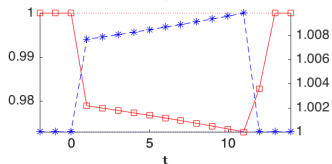
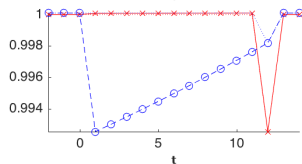
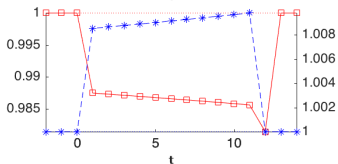
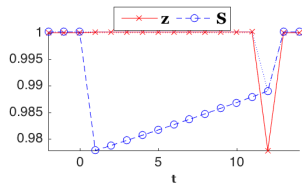
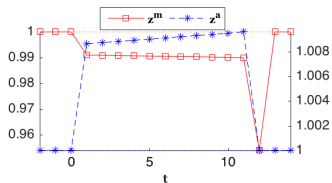
- ▶ Target  $i_t = \phi_t / \beta \phi_{t+1} - 1$ .
- ▶ Benchmark case:  $i_t = \alpha \lambda(z_t)$  kills the dynamics.
- ▶ Money and asset:

$$i_t = \alpha_m \lambda(z_t^m) + \alpha_b \lambda(z_t)$$

$$z_{t-1}^a = \beta z_t^a \{1 + \chi [\alpha_a \lambda(z_t^a) + \alpha_b \lambda(z_t)]\} + \chi \rho_{t-1}$$

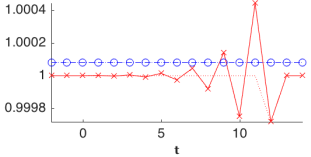
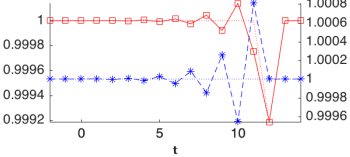
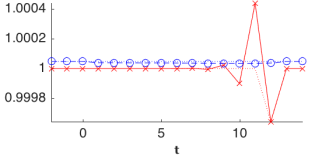
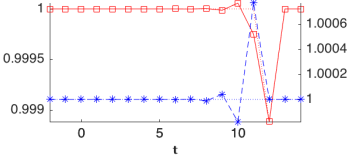
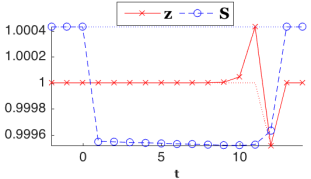
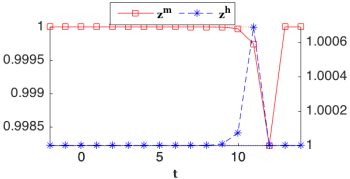
- ▶ Similar for two monies, money and credit, money and housing

# Effects of Nominal Rate on Asset Market



Money-and-Asset Economy, Interest Target, Increase in  $i$

# Effects of Nominal Rate on Housing Market



Housing-and-Money Economy, Interest Target, Increase in  $i$

## Lesson 7

- ▶ Under an interest rate rule, productivity or policy news can induce dynamics in goods and asset prices, news about one country can induce dynamics in both countries, and news about credit conditions can induce dynamics in the value of money and debt limits.
- ▶ It is more difficult to get oscillations under an interest rate rule,
- ▶ With housing in the model news can induce intricate dynamics in goods and house prices with more oscillations.

Here endeth the lessons.



# Conclusion

- ▶ Old monetarists were concerned about long and variable lags; we focus here on long and variable leads.
- ▶ Announcements accentuate rather than attenuate volatility.
- ▶ Money injections have real effects iff they are anticipated.
  - ▶ makes neutrality hard to identify in data
  - ▶ the fact that markets respond to Fed news does not imply it controls anything of fundamental importance
- ▶ Volatility can improve welfare, but exploiting this is hard.