Recent Developments in Monetary Economics

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Overview

- A new consensus has emerged about the rough outlines of a model for the analysis of monetary policy.
  – Consensus influenced heavily by estimated impulse response functions from Structural Vector Autoregression (SVARs)
- Describe empirical SVAR results.
- Construction of the consensus models based on results from SVARs.
  – Christiano, Eichenbaum and Evans JPE (2005)
  – Smets and Wouters, AER (2007)
- Further developments of the consensus model
  – Labor market
  – Financial frictions
  – Open economy
- Policy analysis: how monetary policy may inadvertedly contribute to excess asset market volatility.

Vector Autoregressions

- Proposed by Chris Sims in 1970s, 1980s
- Major subsequent contributions by others (Bernanke, Blanchard-Watson, Blanchard-Quah)
- Useful Way to Organize Data
  – VARs serve as a 'Battleground' between alternative economic theories
  – VARs can be used to quantitatively construct a particular model
- Question that can (in principle) be addressed by VAR:
  – 'How does the economy respond to a particular shock?'
  – Current consensus model heavily guided by answers to this question
- VARs can't *actually* address such a question
  – Identification problem
  – Need extra assumptions….Structural VAR (SVAR).

Outline of SVAR discussion

- What is a VAR?
- The Identification Problem
- Identification restrictions
- Results
- Historical Decompositions of Data

Estimating the Effects of Shocks to the Economy

- Vector Autoregression for a $N \times 1$ vector of observed variables:

$$Y_t = B_1 Y_{t-1} + \ldots + B_p Y_{t-p} + u_t,$$

$$E u_t u_t' = V$$

- $B\prime s$, $u's$ and V are Easily Obtained by OLS.
- Problem: $u's$ are statistical innovations.
  - We want impulse response functions to fundamental economic shocks, e_t.

$$u_t = C e_t,$$

$$E e_t e_t' = I,$$

$$CC' = V$$

Estimating the Effects of a Shock to the Economy ...

$$\text{VAR:} \quad Y_t = B_1 Y_{t-1} + \ldots + B_p Y_{t-p} + C e_t$$

- Impulse Response to i^{th} Shock:

$$Y_t - E_{t-1} Y_t = C_i e_{it},$$

$$E_t Y_{t+1} - E_{t-1} Y_{t+1} = B_1 C_i e_{it}$$

$$\ldots$$

- To Compute Dynamic Response of Y_t to i^{th} Element of e_t We Need

$$B_1, \ldots, B_p \text{ and } C_i.$$

Identification Problem

$$Y_t = B_1 Y_{t-1} + \ldots + B_p Y_{t-p} + u_t$$

$$u_t = C e_t, \; E u_t u_t' = CC' = V$$

- We know $B's$ and V, we need C.
- Problem
  - N^2 Unknown Elements in C,
  - Only $N(N+1)/2$ Equations in

$$CC' = V$$

- Identification Problem: Not Enough Restrictions to Pin Down C
- Need More Identifying Restrictions!

Shocks and Identification Assumptions

- Monetary Policy Shock
- Neutral Technology Shock
- Capital-Embodied Shock to Technology

Identifying Monetary Policy Shocks

- One strategy: estimate parameters of Fed's feedback rule
  - Rule that relates Fed's actions to state of the economy:

Fed information set → Policy shock

$$R_t = f(\Omega_t) + e_t^R$$

  - f linear
  - e_t^R orthogonal to Fed information, Ω_t
  - Ω_t contains current prices and wages, aggregate quantities, lagged stuff
  - e_t^R estimated by OLS regression
  - Regress X_t on e_t^R, e_{t-1}^R, e_{t-2}^R, ...

Identification of Technology Shocks (Blanchard-Quah, Fisher, JPE 2007)

- There are two types of technology shocks: neutral and capital embodied

$$X_t = Z_t F(K_t, L_t)$$

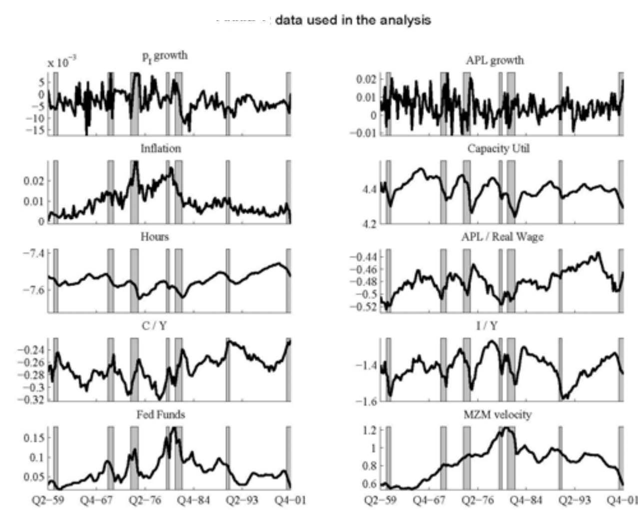
$$K_{t+1} = (1-\delta)K_t + V_t I_t$$

- These are only shocks that can affect labor productivity in the long run.
- The only shock which also has a long run effect on the relative price of capital is a capital embodied technology shock (V_t).

VAR estimation with the following data:

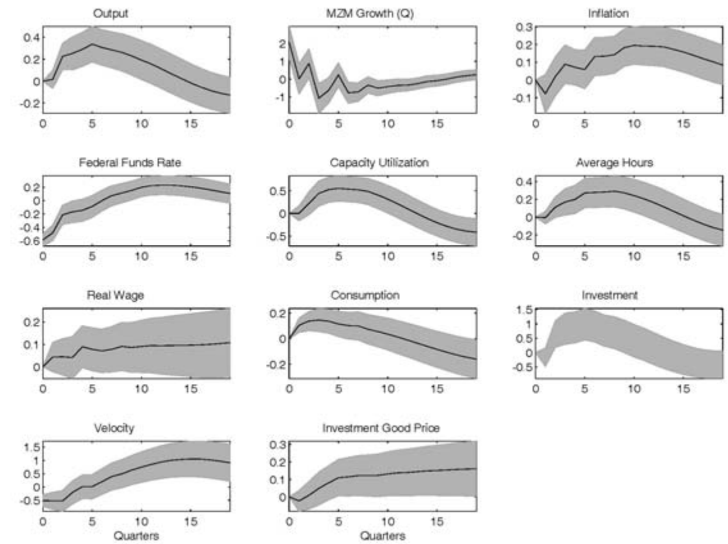
$$\underbrace{Y_t}_{10\times 1} = \begin{pmatrix} \Delta \ln(\text{relative price of investment}_t) \\ \Delta \ln(GDP_t/\text{Hours}_t) \\ \Delta \ln(GDP \text{ deflator}_t) \\ \text{capacity utilization}_t \\ \ln(\text{Hours}_t) \\ \ln(GDP_t/\text{Hours}_t) - \ln(W_t/P_t) \\ \ln(C_t/GDP_t) \\ \ln(I_t/GDP_t) \\ \text{Federal Funds Rate}_t \\ \ln(GDP \text{ deflator}_t) + \ln(GDP_t) - \ln(MZM_t) \end{pmatrix}$$

The data have been transformed to ensure stationarity
Sample period: 1959Q1-2007Q1



- Results…..

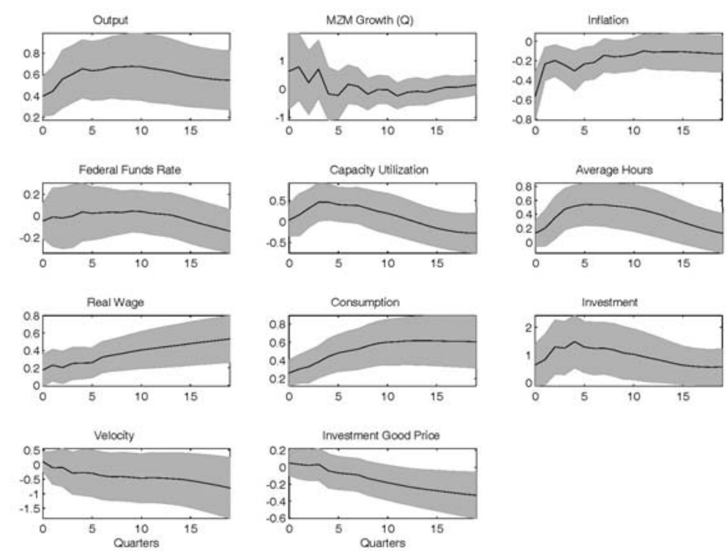
Response to a monetary policy shock



Interesting Properties of Monetary Policy Shocks

- Plenty of endogenous persistence:
  - money growth and interest rate over in 1 year, but other variables keep going….
- Inflation slow to get off the ground: peaks in roughly two years
  - It has been conjectured that explaining this is a major challenge for economics
  - Chari-Kehoe-McGrattan (*Econometrica*), Mankiw.
  - Kills models in which movements in *P* are key to monetary transmission mechanism (Lucas misperception model, pure sticky wage model)
  - Has been at the heart of the recent emphasis on sticky prices.
- Output, consumption, investment, hours worked and capacity utilization hump-shaped
- Velocity comoves with the interest rate

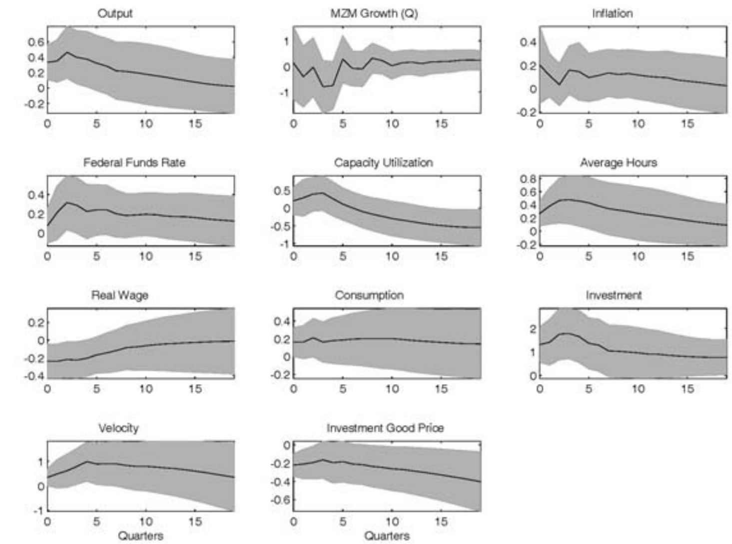
Response to a neutral technology shock



Observations on Neutral Shock

- Generally, results are ‘noisy’, as one expects.
  - Interest, money growth, velocity responses not pinned down.
- Interestingly, inflation response is immediate and *precisely* estimated.
- Does this raise a question about the conventional interpretation of the response of inflation to a monetary shock?
- Alternative possibility: information confusion stories.
  - A variant of recent work by Rhys Mendes that builds on Guido Lorenzoni’s work.

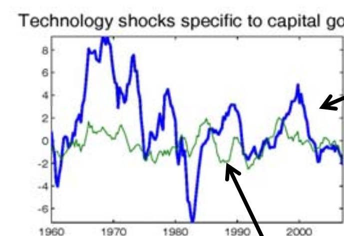
Response to an embodied technology shock



Historical Decomposition of Data into Shocks

- We can ask:
  - What would have happened if only monetary policy shocks had driven the data?
  - We can ask this about other identified shocks, or about combinations of shocks
  - We find that the three shocks together account for a large part of fluctuations

Historical decomposition of US GDP

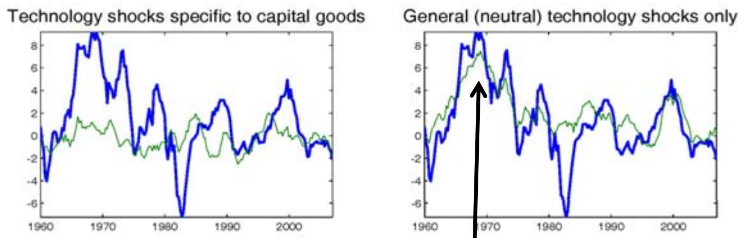


Dark line: detrended actual GDP

Thin line: what GDP would have been if there had only been one type of technology shock, the type that affects only the capital goods industry

These shocks have some effect, but not terribly important

Historical decomposition of US GDP

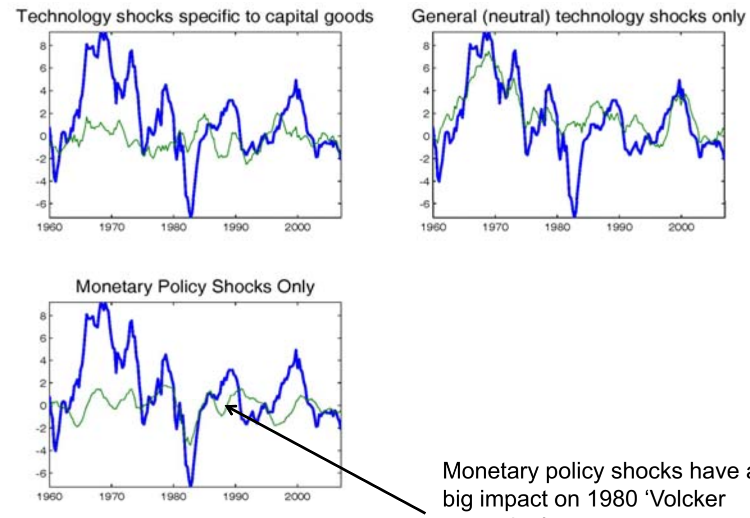


Type of technology shock that affects all industries

This has very large impact on broad trends in the data, and a smaller impact on business cycles.

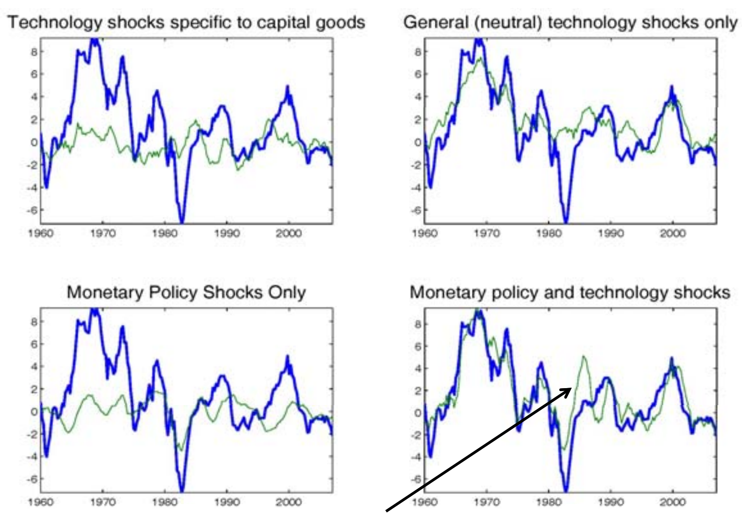
Has big impact on trend in data, and 2000 boom-bust

Historical decomposition of US GDP



Monetary policy shocks have a big impact on 1980 'Volcker recession'

Historical decomposition of US GDP



All three shocks together account for large part of business cycle

Variance Decomposition

Variable	BP(8,32)
Output	86 [18]
Money Growth	23 [11]
Inflation	33 [17]
Fed Funds	52 [16]
Capacity Util.	51 [16]
Avg. Hours	76 [17]
Real Wage	44 [16]
Consumption	89 [21]
Investment	69 [16]
Velocity	29 [16]
Price of investment goods	11 [16]

Figure 4: Historical decomposition - monetary policy and technology shocks

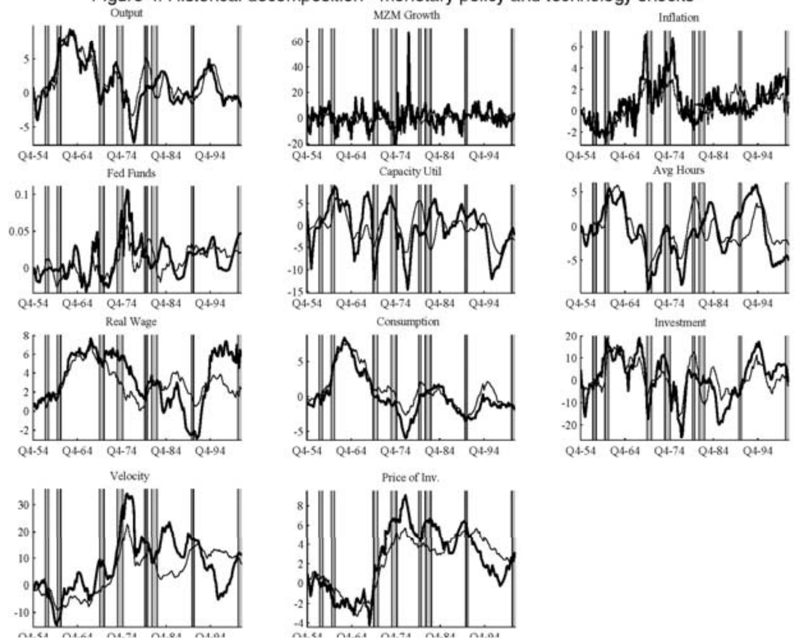


Table 1: Decomposition of Variance - In-sample Band Pass Filter and 30-Quarter Ahead Forecast Error

Variable	Embodied Technology		Neutral Technology		Monetary Policy		All Three Shocks	
	BP(8,32)	Forec. Error	BP(8,32)	Forec. Error	BP(8,32)	Forec. Error	BP(8,32)	Forec. Error
Output	19 [10]	10 [8]	22 [13]	63 [15]	25 [9]	6 [3]	86 [18]	80 [12]
MZM Growth	2 [6]	3 [3]	3 [7]	3 [3]	17 [7]	13 [3]	23 [11]	18 [5]
Inflation	3 [10]	7 [11]	16 [12]	25 [9]	15 [7]	11 [5]	33 [17]	43 [11]
Fed Funds	6 [9]	14 [9]	2 [7]	1 [5]	45 [10]	20 [5]	52 [16]	36 [9]
Capacity Util.	7 [9]	13 [9]	7 [8]	7 [6]	25 [9]	11 [5]	51 [16]	31 [10]
Avg. Hours	19 [11]	19 [11]	18 [11]	34 [13]	22 [8]	7 [4]	76 [17]	60 [13]
Real Wage	28 [11]	5 [10]	7 [12]	49 [19]	2 [3]	2 [3]	44 [16]	57 [17]
Consumption	14 [10]	8 [11]	37 [17]	71 [20]	23 [8]	2 [3]	89 [21]	82 [17]
Investment	19 [10]	30 [12]	10 [10]	22 [12]	20 [8]	7 [4]	69 [16]	59 [12]
Velocity	7 [10]	11 [13]	1 [8]	5 [7]	24 [10]	12 [6]	29 [16]	27 [13]
Price of Inv.	9 [16]	26 [20]	4 [7]	13 [10]	3 [4]	5 [4]	11 [16]	44 [16]

Notes: Numbers are point estimates, number in square brackets are standard deviation of point estimates across bootstrap simulations. In the case of the forecast error decomposition row sums fail to add only because of rounding error. In the case of BP(8,32) row sums fail to add due to in-sample correlation between shocks.

- Now, to the construction of a monetary equilibrium model, based on the previous impulse response functions….

- Based on
  - Christiano-Eichenbaum-Evans JPE(2005)
  - Altig-Christiano-Eichenbaum-Linde

Objectives

- Constructing a standard ('consensus') DSGE Model
  - Model features.
  - Estimation of model using impulse responses from SVAR's.

- Determine if there is a conflict regarding price behavior between micro and macro data.

  - Macro Evidence:
    - Inflation appears sluggish
    - Inflation responds slowly to monetary shock

  - Micro Evidence:
    - Bils-Klenow, Nakamura-Steinsson report evidence on frequency of price change at micro level: 5-11 months.

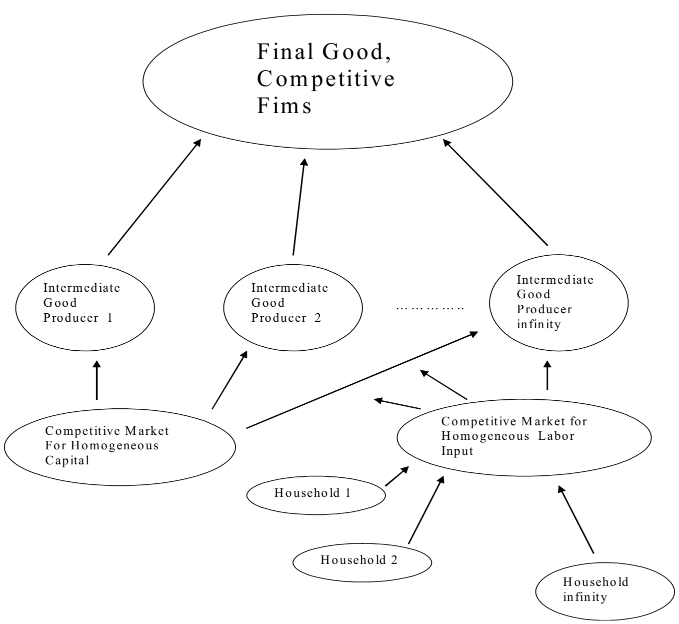
Description of Model

- Timing Assumptions
- Firms
- Households
- Monetary Authority
- Goods Market Clearing and Equilibrium

Timing

- Technology Shocks Realized.
- Agents Make Price/Wage Setting, Consumption, Investment, Capital Utilization Decisions.
- Monetary Policy Shock Realized.
- Household Money Demand Decision Made.
- Production, Employment, Purchases Occur, and Markets Clear.
-
- Note: Wages, Prices and Output Predetermined Relative to Policy Shock.

Firm Sector



Firms

Final Good Firms

- Technology:

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{1}{\lambda_f}} di\right]^{\lambda_f}, \; 1 \leq \lambda_f < \infty$$

- Objective:

$$\max P_t Y_t - \int_0^1 P_{it} Y_{it} di$$

- Foncs and Prices:

$$\left(\frac{P_t}{P_{it}}\right)^{\frac{\lambda_f}{\lambda_f - 1}} = \frac{Y_{it}}{Y_t}, \; P_t = \left[\int_0^1 P_{it}^{\frac{1}{1-\lambda_f}} di\right]^{(1-\lambda_f)}.$$

Intermediate Good Firms -

- Each Y_{it} Produced by a Monopolist, With Demand Curve:

$$\left(\frac{P_t}{P_{it}}\right)^{\frac{\lambda_f}{\lambda_f-1}} = \frac{Y_{it}}{Y_t}.$$

- Technology:

$$Y_{it} = K_{it}^{\alpha}\left(z_t L_{it}^{1-\alpha}\right),\ 0 < \alpha < 1,$$

- Here, z_t is a technology shock:

$$\mu_{z,t} = \log z_t - \log z_{t-1},\ \hat{\mu}_{z,t} = \rho_{\mu_z}\hat{\mu}_{z,t-1} + \varepsilon_{\mu_z,t}$$

- Calvo Price Setting:
  - With Probability $1-\xi_p$, i^{th} Firm Sets Price, P_{it}, Optimally, to $\tilde{P}_t$.
  - With Probability ξ_p,

$$P_{it} = \pi_{t-1}P_{i,t-1},\ \pi_t = \frac{P_t}{P_{t-1}}.$$

  - Standard Approach in Literature:

$$P_{it} = \bar{\pi}P_{i,t-1},\ \text{or}$$
$$P_{it} = P_{i,t-1}.$$

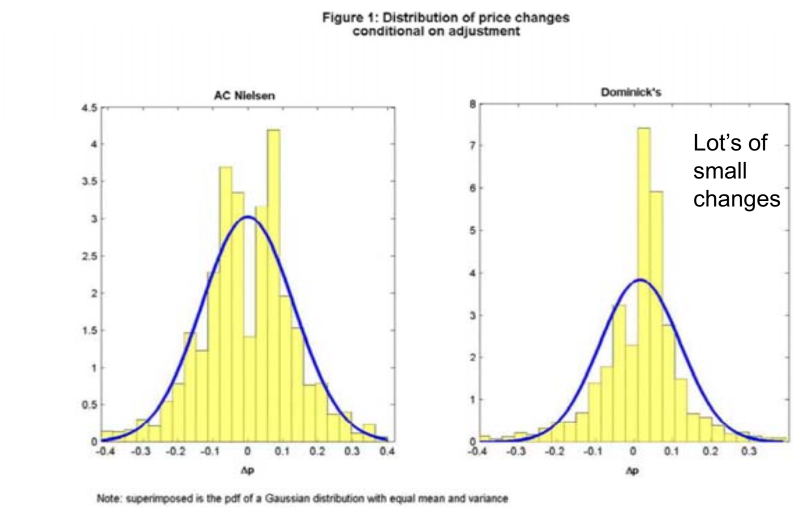
  - Stand on Indexing Matters

    Determines Extent of 'Front-Loading'

Is Calvo a Good Reduced Form Model of Sticky Prices?

- Evidence on relative frequency of large and small price changes suggests 'yes'
- Evidence of probability of price change conditional on time since last change suggests 'yes'

Evidence from Midrigan, 'Menu Costs, Multi-Product Firms, and Aggregate Fluctuations'



Histograms of $\log(P_t/P_{t-1})$, conditional on price adjustment, for two data sets pooled across all goods/stores/months in sample.

- Combining Optimal Price and Aggregate Price Relation:

$$\Delta\hat{\pi}_t = \beta E_t \Delta\hat{\pi}_{t+1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p} E_t \hat{s}_t,$$

- Under Standard Price-Updating Scheme:

$$P_{it} = \bar{\pi} P_{i,t-1}.$$

Associated Reduced Form:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p} E_t \hat{s}_t.$$

Households: Sequence of Events

- Technology shock realized.
- Decisions: Consumption, Capital accumulation, Capital Utilization.
- Insurance markets on wage-setting open.
- Wage rate set.
- Monetary policy shock realized.
- Household allocates beginning of period cash between deposits at financial intermediary and cash to be used in consumption transactions.

Households...

- Monopoly supplier of differentiated labor
  - Sets wage subject to Calvo style frictions like firms
- Preferences of j^{th} household

$$E_t^j \sum_{l=0}^{\infty} \beta^{l-t} \left[\log\left(C_{t+l} - bC_{t+l-1}\right) - \psi_L \frac{h_{j,t+l}^2}{2} \right]$$

- E_t^j : expectation operator, conditional on aggregate and household j idiosyncratic information.
- C_t : consumption
- h_{jt} : hours worked.

Households...

- Asset Evolution Equation:

$$\begin{aligned} M_{t+1} &= R_t \left[M_t - Q_t + (x_t - 1) M_t^a \right] + A_{j,t} + Q_t + W_{j,t} h_{j,t} \\ &\quad + P_t r_t^k u_t \bar{K}_t + D_t - P_t \left[(1 + \eta(V_t)) C_t + \Upsilon_t^{-1} \left(I_t + a(u_t) \bar{K}_t \right) \right] \end{aligned}$$

  - M_t : Beginning of Period Base Money; Q_t : Transactions Balances
  - x_t : Growth Rate of Base; u_t : Utilization Rate of Capital
    - $u_t = 1$ in steady state, $a(1) = 0$, $a'(1) > 0$, $\sigma_a = a''(1)/a'(1)$.
  - Υ_t^{-1}: (Real) Price of investment goods, $\mu_{\Upsilon,t} = \Upsilon_t / \Upsilon_{t-1}$,

$$\hat{\mu}_{\Upsilon,t} = \rho_{\mu_\Upsilon} \hat{\mu}_{\Upsilon,t-1} + \varepsilon_{\mu_\Upsilon,t}$$

- Velocity:

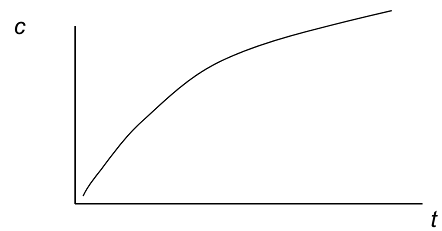
$$V_t = \frac{P_t C_t}{Q_t},$$

Dynamic Response of Consumption to Monetary Policy Shock

- In Estimated Impulse Responses:
  - Real Interest Rate Falls

$$R_t/\pi_{t+1}$$

  - Consumption Rises in Hump-Shape Pattern:



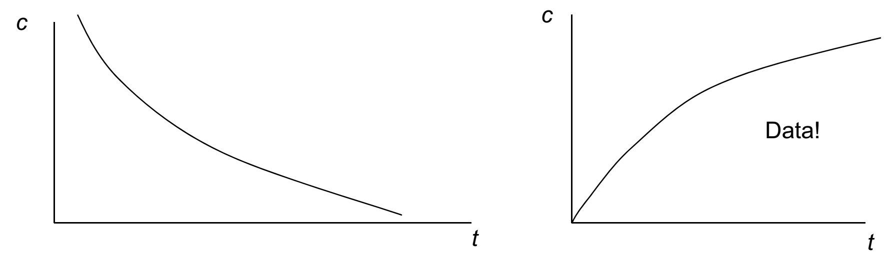
Consumption 'Puzzle'

- Intertemporal First Order Condition:

'Standard' Preferences →

$$\frac{c_{t+1}}{\beta c_t} = \frac{MU_{c,t}}{\beta MU_{c,t+1}} \approx R_t/\pi_{t+1}$$

- With Standard Preferences:



One Resolution to Consumption Puzzle

- Concave Consumption Response Displays:
  - Rising Consumption (problem)
  - Falling Slope of Consumption
- Habit Persistence in Consumption

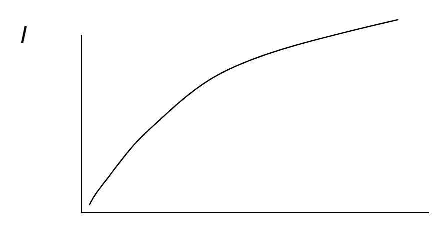
Habit parameter → b

$$U(c) = \log(c - b \times c_{-1})$$

  - Marginal Utility Function of *Slope* of Consumption
  - Hump-Shape Consumption Response Not a Puzzle
- Econometric Estimation Strategy Given the Option, *b>0*

Dynamic Response of Investment to Monetary Policy Shock

- In Estimated Impulse Responses:
  - Investment Rises in Hump-Shaped Pattern:



One Solution to Investment Puzzle…

- Cost-of-Change Adjustment Costs:

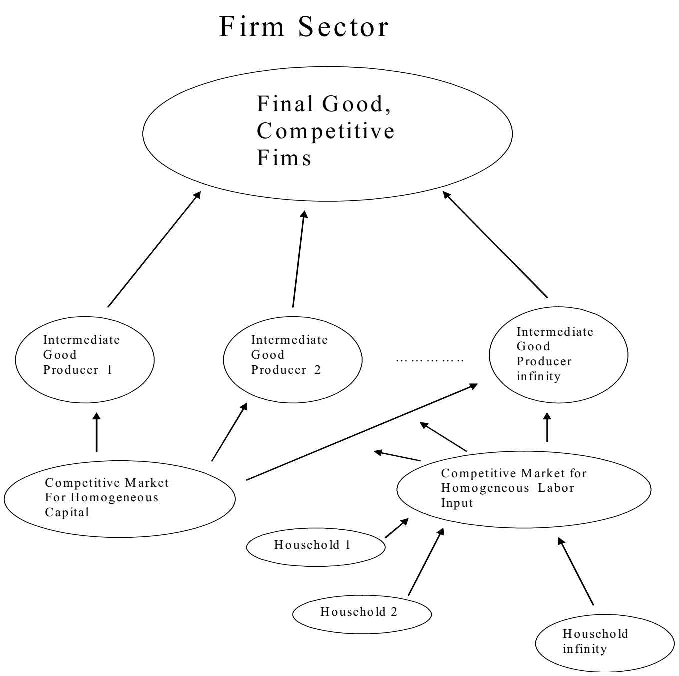
$$k' = (1 - \delta)k + F\left(\frac{I}{I_{-1}}\right)I$$

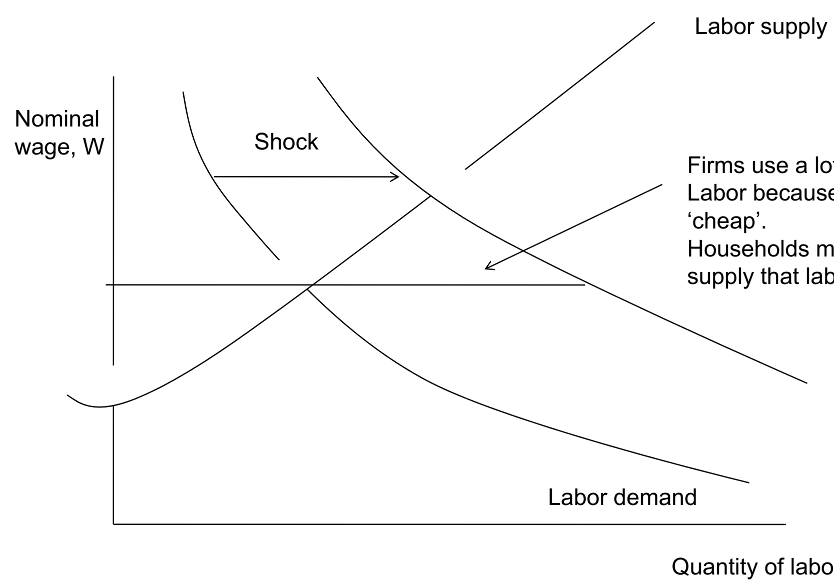
- This Does Produce a Hump-Shape Investment Response
  - Other Evidence Favors This Specification
  - Empirical: Matsuyama, Smets-Wouters.
  - Theoretical: Matsuyama, David Lucca

Wage Decisions

- Each household is a monopoly supplier of a specialized, differentiated labor service.
  - Sets wages subject to Calvo frictions.
  - Given specified wage, household must supply whatever quantity of labor is demanded.
- Household differentiated labor service is aggregated into homogeneous labor by a competitive labor 'contractor'.

$$l_t = \left[\int_0^1 (h_{t,j})^{\frac{1}{\lambda_w}} dj\right]^{\lambda_w},\ 1 \leq \lambda_w < \infty.$$





Monetary and Fiscal Policy

$$x_t = M_t / M_{t-1}$$

$$\begin{aligned}\hat{x}_{M,t} &= \rho_M \hat{x}_{M,t-1} + \varepsilon_{M,t} \\ \hat{x}_{z,t} &= \rho_{xz} \hat{x}_{z,t-1} + c_z \varepsilon_{z,t} + c_z^p \varepsilon_{z,t-1} \\ \hat{x}_{\Upsilon,t} &= \rho_{x\Upsilon} \hat{x}_{\Upsilon,t-1} + c_\Upsilon \varepsilon_{\Upsilon,t} + c_\Upsilon^p \varepsilon_{\Upsilon,t-1}\end{aligned}$$

- $\hat{x}_{M,t}$: response of monetary policy to a monetary policy shock, $\varepsilon_{M,t}/$
- $\hat{x}_{z,t}$: response of monetary policy to an innovation in neutral technology, $\varepsilon_{z,t}$.
- $\hat{x}_{\Upsilon,t}$: response of monetary policy to an innovation in capital embodied technology, $\varepsilon_{\Upsilon,t}$.
- Government has access to lump sum taxes, pursues a Ricardian fiscal policy.

Loan Market and Final Good Market Clearing Conditions, Equilibrium

- Financial intermediaries receive $M_t - Q_t + (x_t - 1) M_t$ from the household.
  - Lend all of their money to intermediate good firms, which use the funds to pay for H_t.
- Loan market clearing

$$W_t H_t = x_t M_t - Q_t.$$

- The aggregate resource constraint is

$$(1 + \eta(V_t))C_t + \Upsilon_t^{-1}\left[I_t + a(u_t)\bar{K}_t\right] \le Y_t.$$

- We adopt a standard sequence-of-markets equilibrium concept.

Econometric Methodology

- Choose parameters of economic model, so that the dynamic response to shocks resembles as closely as possible the impulse responses estimated from SVARs.
- Make sure that identifying assumptions used in the SVAR are satisfied in the model.

Estimating Parameters in the Model

- Partition Parameters into Three Groups.
  - Parameters set a priori (e.g., β, δ,...)
  - ζ_1: remaining parameters pertaining to the nonstochastic part of model

$$\zeta_2 = [\xi_w, \gamma, \sigma_a, b, S'', \epsilon]$$

  - ζ_2: parameters pertaining to stochastic part of the model
- Number of parameters, $\zeta = (\zeta_1, \zeta_2)$, to be estimated - 18
- Estimation Criterion
  - $\Psi(\zeta)$: mapping from ζ to model impulse responses
  - $\hat{\Psi}$: 592 impulse responses estimated using VAR
  - Estimation Strategy:

$$\hat{\zeta} = \arg\min_{\zeta} \left(\hat{\Psi} - \Psi(\zeta)\right)' V^{-1} \left(\hat{\Psi} - \Psi(\zeta)\right).$$

  - V: diagonal matrix with sample variances of $\hat{\Psi}$ along the diagonal.

- Parameter estimates

TABLE 2: ESTIMATED PARAMETER VALUES ζ_1							
Model	λ_f	ξ_w	γ	σ_a	b	S''	ϵ
Benchmark	1.35 (0.17)	.75 (0.06)	.32 (0.32)	0.06 (0.18)	0.80 (0.04)	4.85 (2.15)	0.77 (0.27)

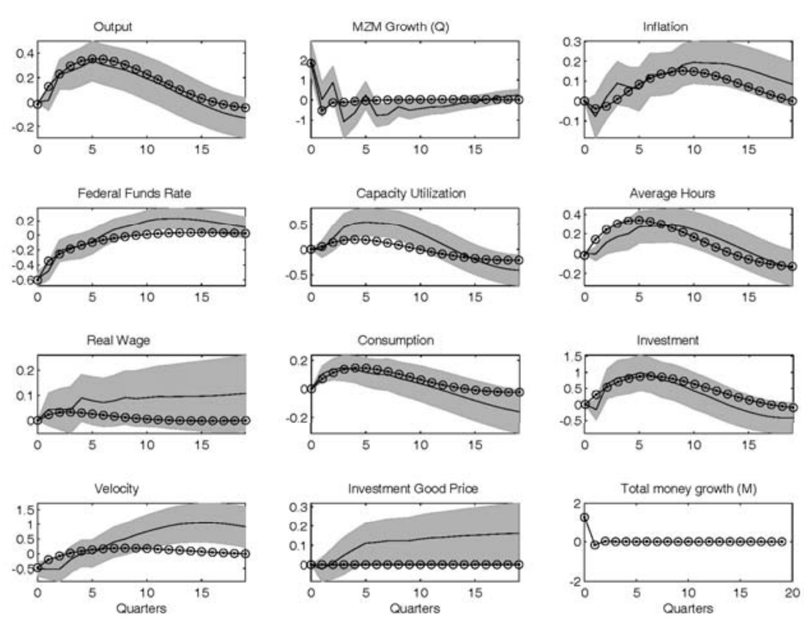
- Parameters are surprisingly consistent with estimates reported in JPE (2005) based on studying only monetary policy shocks
- Point estimates imply prices relatively flexible at micro level
  - At point estimates: $\xi_p = 0.58,\ \frac{1}{1-\xi_p} = 2.38$ quarters
- Other parameters ‘reasonable’: estimation results really want sticky wages!

- Parameters of exogenous shocks:

TABLE 3: ESTIMATED PARAMETER VALUES ζ_2											
ρ_M	σ_M	ρ_{μ_z}	σ_{μ_z}	ρ_{xz}	c_z	c_z^p	ρ_{μ_Υ}	σ_{μ_Υ}	$\rho_{x\Upsilon}$	c_Υ	c_Υ^p
Benchmark Model											
−0.10 (0.12)	0.31 (0.10)	.91 (0.03)	0.05 (0.02)	0.36 (0.22)	3.68 (1.55)	2.49 (1.22)	−0.24 (0.52)	0.17 (0.06)	0.91 (0.07)	−0.10 (0.57)	0.63 (0.65)

- Neutral technology shock, ρ_{μ_z} ,is highly persistent.

Figure 1: Response to a monetary policy shock (o - Model, - VAR, grey area - 95 % Confidence Interval)



Monetary Policy Shock

- Key findings:
  - Can account for sluggish aggregate response to monetary policy shock without a lot of price stickiness
  - Can account for the observed effects of monetary policy on consumption, investment, output, etc.

Figure 2: Response to a neutral technology shock (o - Model, - VAR, grey area - 95 % Confidence Interval)

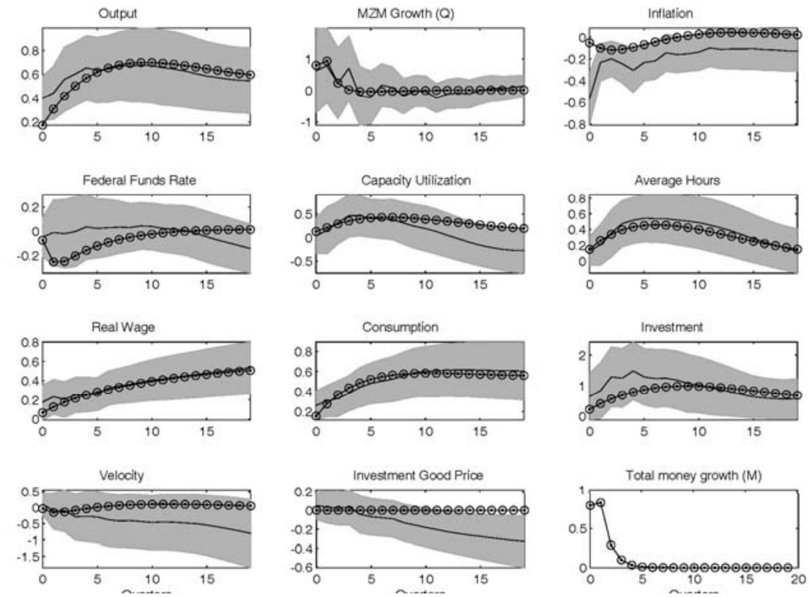


Figure 2: Response to a neutral technology shock (o - Model, - VAR, grey area - 95 % Confidence Interval)

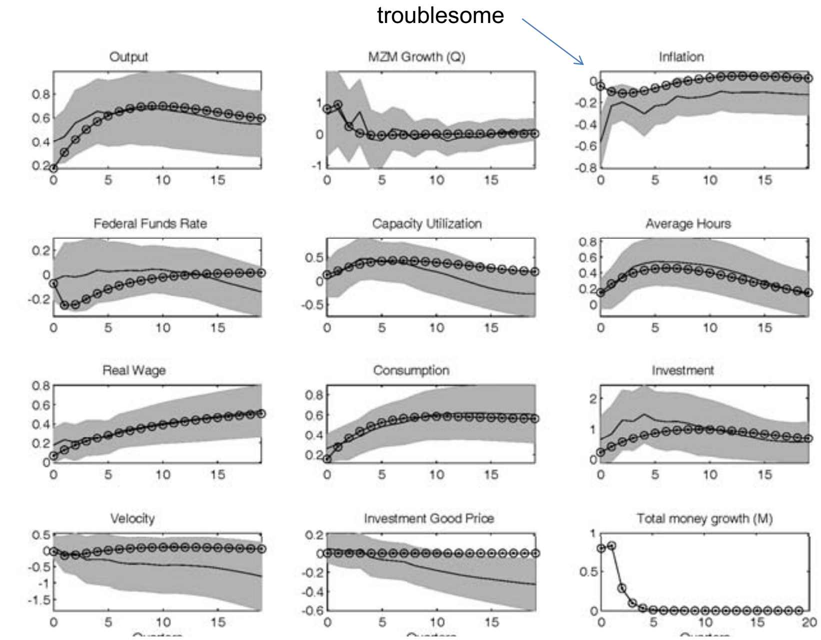
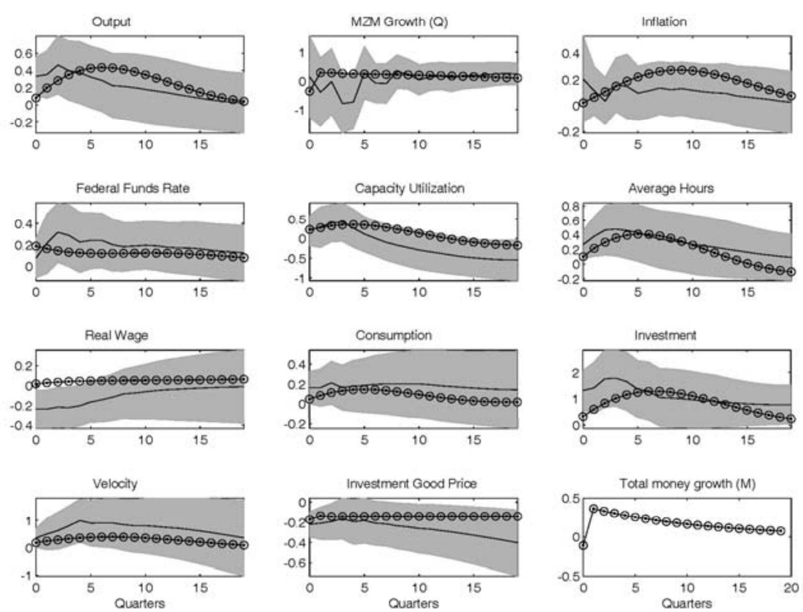


Figure 3: Response to an embodied technology shock (o - Model, - VAR, grey area - 95 % Confidence Interval)



Further work with this model

- Policy questions:
  - role of monetary policy in transmission of technology shocks
  - Role of monetary policy in asset price volatility
- Can construct 'micro panel data sets' implied by model:
  - Gain power to test model by developing its micro implications.
  - What are cross-sectional implications of model for prices and quantities at the firm level?

Implications for Panel Data

- ‘Demand shocks’ for intermediate good firms:

$$Y_t = \left[\int_0^1 (\theta_{it} Y_{it})^{\frac{1}{\lambda_f}}\right]^{\lambda_f}$$

$$\int_0^1 \theta_{it} di = 1,\ \theta_{it} \sim iid \text{ across } i$$

- ‘Supply shocks’ for intermediate good firms:

$$Y_{it} = \eta_{it} K_{it}^{\alpha} (z_t L_{it})^{1-\alpha}$$

$$\eta_{it} \sim iid \text{ across } i$$

Conclusion of ‘Consensus’ Model Construction and Estimation

- Identified features of a model (variable capital utilization, habit persistence, adjustment costs in the change of investment) that allow it to account for estimated SVAR impulse responses.
- The estimation strategy focused on a subset of model implications.
- Full information methods have been used to estimate version of the model with a full set of shocks on the raw data (Smets and Wouters).
- A future phase of empirical work will draw out the implications of macro models for panel data sets.

Additional model development

- Labor market
  - Model has no implications for unemployment, vacancies, hours worked, people employed, separations, etc.
  - Sticky wages in model subject to ‘Barro critique of sticky wages’
- Financial markets
  - Financial markets are not a source of shocks or propagation.
  - Cannot ask: ‘what should monetary authority do in response to increase in interest rate spreads?’

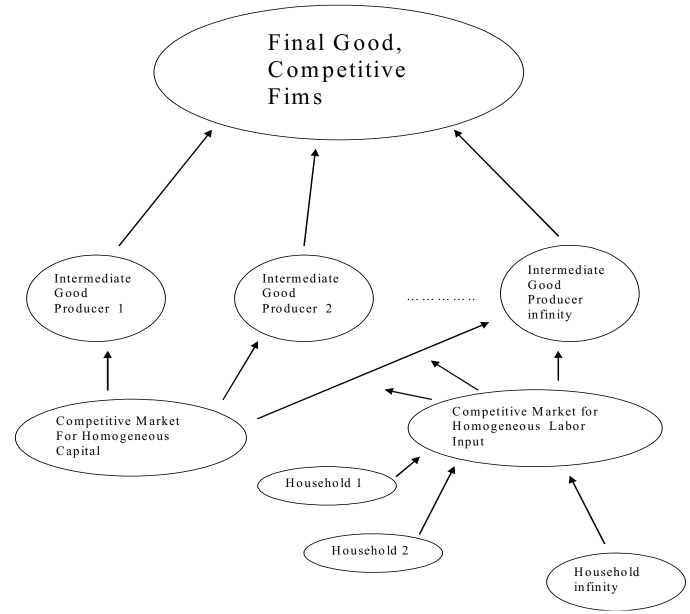
‘Barro critique’

- Most worker-firm relationships are long-term, and unlikely to be strongly affected by details of the timing of wage-setting.
- Standard sticky wage model implausible.
- Recent results in search-matching literature:
  - Must distinguish between intensive (hours) and extensive (employment) margin.
  - Barro critique applies to idea that wage frictions matter in the intensive margin.
  - Does not apply to idea that wage frictions matter for extensive margin.

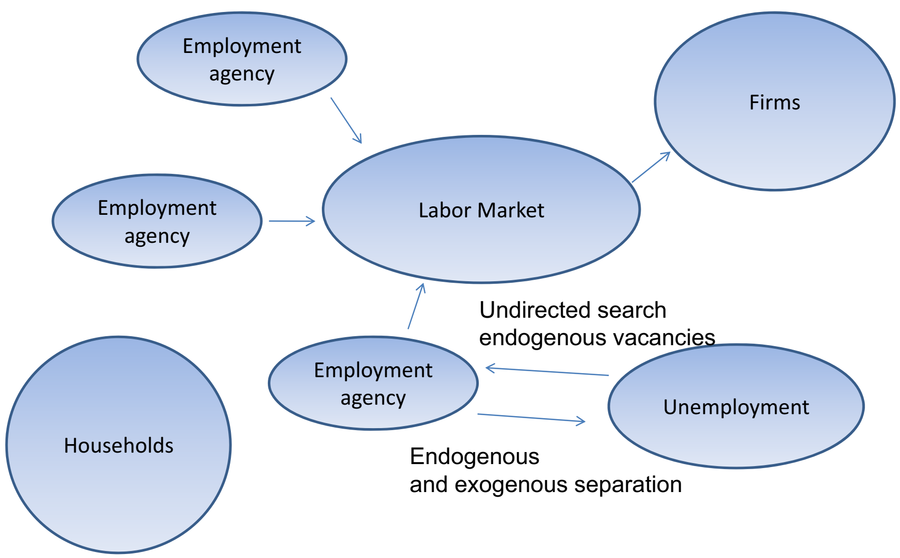
Papers

- Mortensen and Pissarides
- Shimer
- Gertler-Trigari, Gertler-Sala-Trigari
- Hall
- Den Haan, Ramey and Watson
- Christiano, Ilut, Motto, Rostagno
- Christiano, Trabandt, Walentin

Firm Sector



Adding Labor Market Frictions



More on the Labor Market

- Household Preferences

Number of employed workers in cohort i

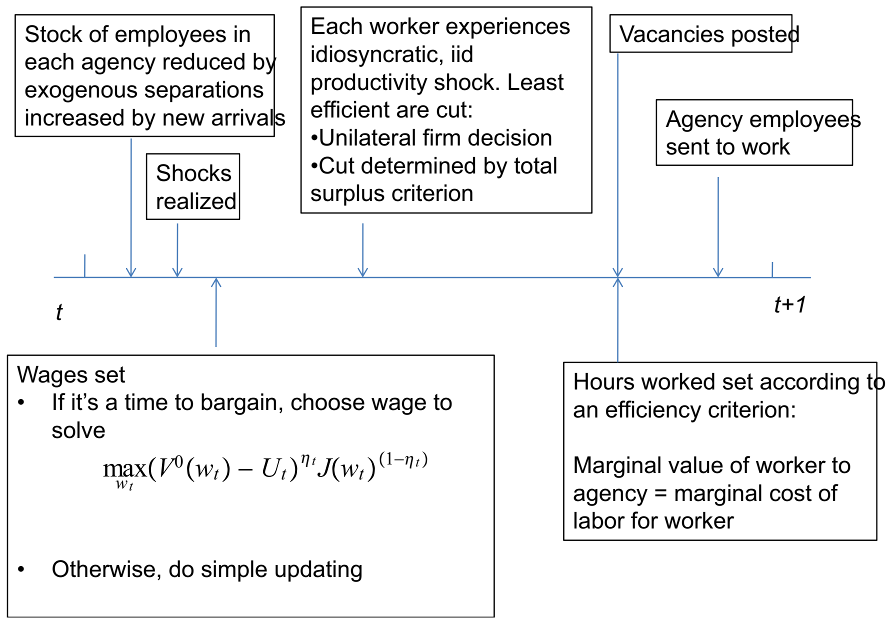
$$E_t \sum_{l=0}^{\infty} \beta^{l-t} \{ \zeta_{t+l}^c \log(C_{t+l} - bC_{t+l-1}) - \zeta_{t+l}^h A_L \left[\sum_{i=0}^{N-1} \frac{(\varsigma_{i,t+l})^{1+\sigma_L}}{1+\sigma_L} L_{t+l}^i \right] \},$$

hours per worker in cohort *i*

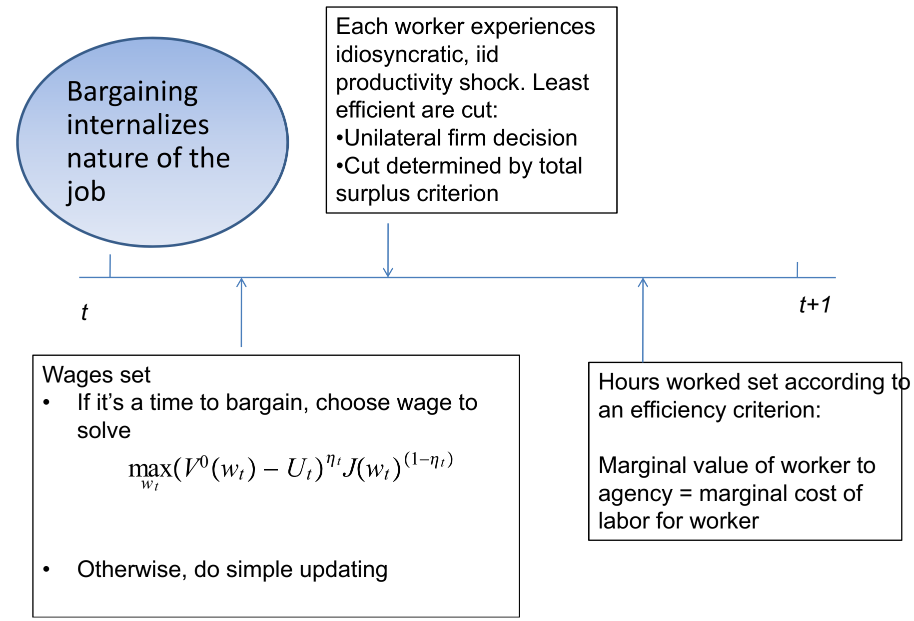
- Worker finances

$$(1-L_t) P_t^c b^u z_t^+ + \sum_{i=0}^{N-1} W_t^i L_t^i \varsigma_{i,t} \frac{1-\tau_t^y}{1+\tau_t^w}$$

Timeline – labor market



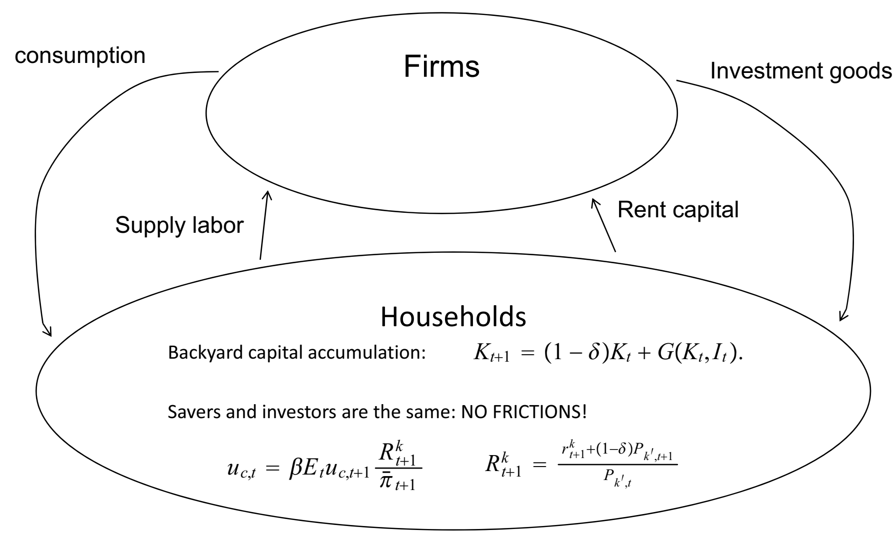
Timeline – labor market



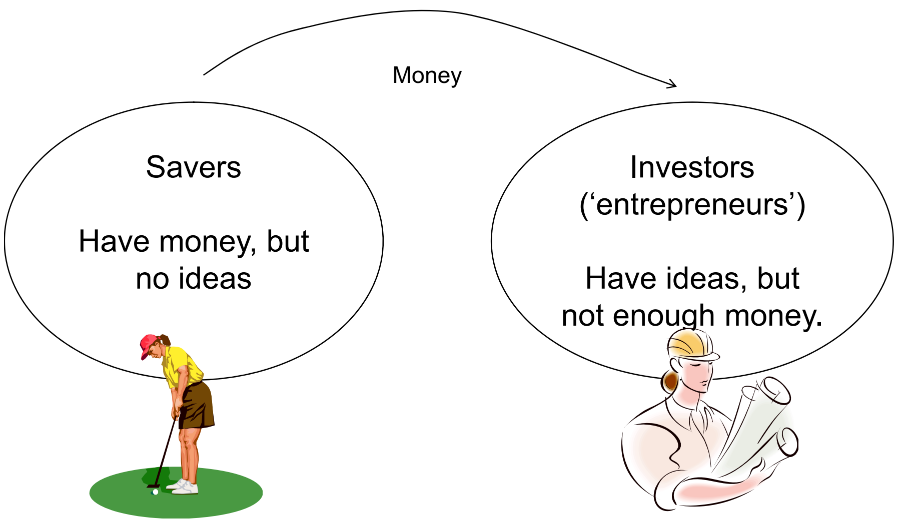
Extension to Incorporate Financial Frictions

- General idea:
  - Standard model assumes borrowers and lenders are the same people..no conflict of interest
  - Financial friction models suppose borrowers and lenders are different people, with conflicting interests
  - Financial frictions: features of the relationship between borrowers and lenders adopted to mitigate conflict of interest.

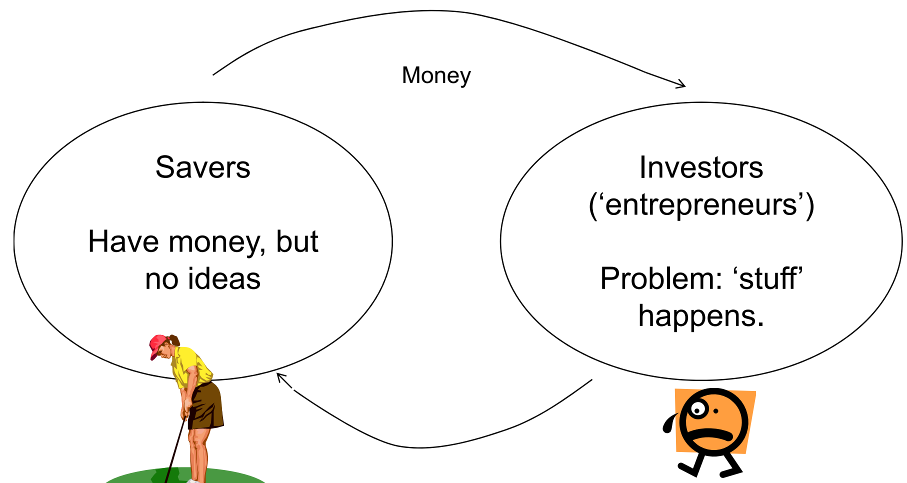
Standard Model



Frictions in Financing of Physical Capital



Frictions in Financing of Physical Capital



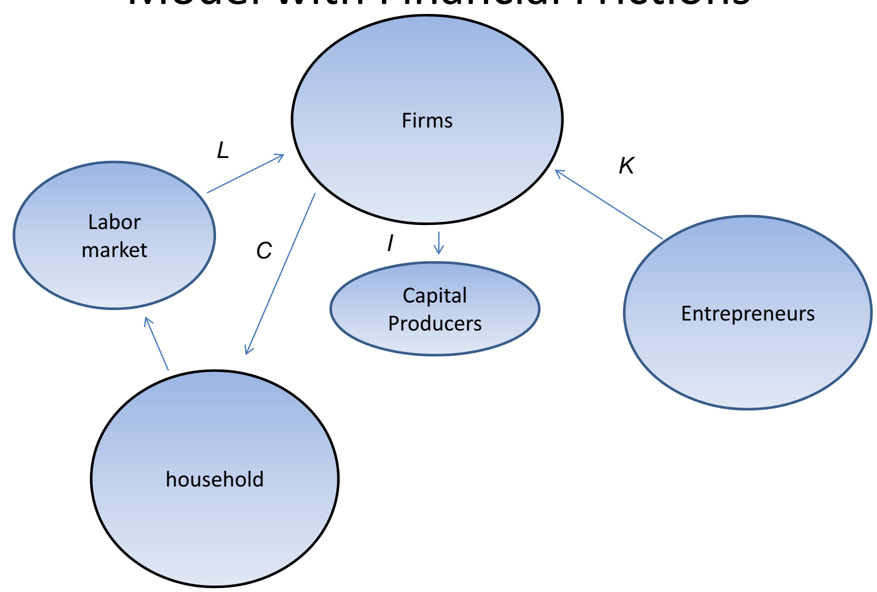
Entrepreneurs (BGG)

- Own and Rent the Stock of Capital
- Period t :
  - Go to bank with own net worth and obtain loan
  - Purchase new capital from capital producers: $\bar{K}_{t+1}$
  - Experience an idiosyncratic productivity shock: $\omega \bar{K}_{t+1}$, $\omega \sim F(\omega; \sigma_t)$
- Periot $t+1$:
  - Choose capital utilization rate and rent out capital services: $u_{t+1}\omega\bar{K}_{t+1}$
  - Cost of utilization: $\tau^{oil}_{t+1} a(u_{t+1})\Upsilon^{-(t+1)}\omega\bar{K}_{t+1}$

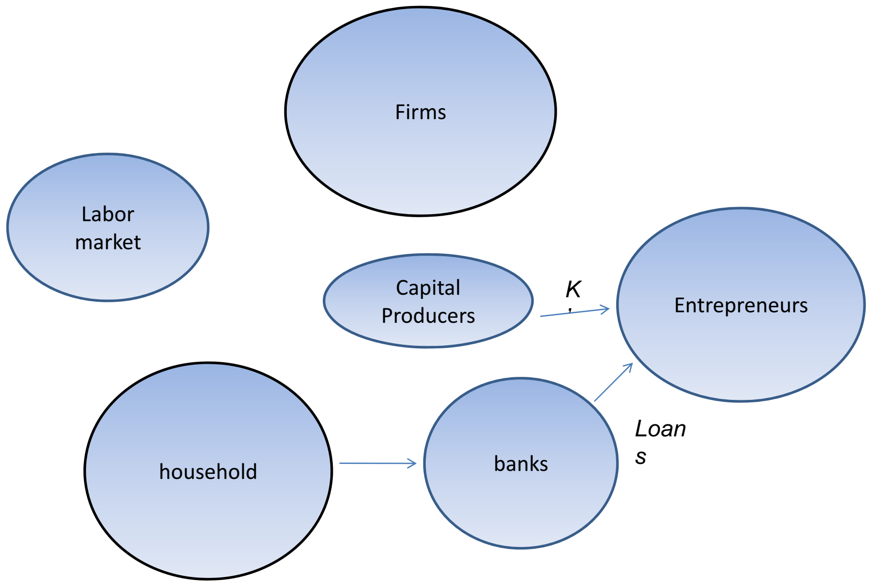
$$V_{t+1} = \text{real earnings on capital (rent plus capital gains)}_t - \frac{\text{nominal rate of interest}_{t-1}}{\pi_t}\text{real debt to banks}_{t-1}$$

$$\text{Net Worth}_{t+1} = \gamma(V_{t+1} + W^e_{t+1}) + (1-\gamma)W^e_{t+1}$$

Model with Financial Frictions



Model with Financial Frictions



Prediction of financial friction model:

- Shocks that drive output and price in the same direction ('demand') accelerated by financial frictions.
  - Fisher and earnings effects reinforce each other.
- Shocks that drive output and price in opposite directions ('supply') not much affected by financial frictions.
  - Fisher and earnings effects cancel each other.

Empirical Analysis of Financial Friction Model

- Christiano-Motto-Rostagno (2008), based on Bernanke-Gertler-Gilchrist (1999) model of financial frictions.

Risk Shock and News

- Assume

$$\hat{\sigma}_t = \rho_1 \hat{\sigma}_{t-1} + \overbrace{u_t}^{\text{iid, univariate innovation to } \hat{\sigma}_t}$$

- Agents have advance information about pieces of u_t

$$u_t = \xi_t^0 + \xi_{t-1}^1 + \ldots + \xi_{t-8}^8$$

$$\xi_{t-i}^i \sim \text{iid}, E(\xi_{t-i}^i)^2 = \sigma_i^2$$

$$\xi_{t-i}^i \sim \text{piece of } u_t \text{ observed at time } t-i$$

Estimation

- EA and US data covering 1985Q1-2007Q2

$$X_t = \begin{pmatrix} \Delta\log\left(\frac{N_{t+1}}{P_t}\right) \\ \pi_t \\ \log(\text{per capita hours}_t) \\ \Delta\log\left(\frac{\text{per capita credit}_t}{P_t}\right) \\ \Delta\log(\text{per capita GDP}_t) \\ \Delta\log\left(\frac{W_t}{P_t}\right) \\ \Delta\log(\text{per capita } I_t) \\ \Delta\log\left(\frac{\text{per capita } M1_t}{P_t}\right) \\ \Delta\log\left(\frac{\text{per capita } M3_t}{P_t}\right) \\ \Delta\log(\text{per capita consumption}_t) \\ \text{External Finance Premium}_t \\ R_t^{long} - R_t^e \\ R_t^e \\ \Delta\log P_{I,t} \\ \Delta\log \text{real oil price}_t \\ \Delta\log\left(\frac{\text{per capita Bank Reserves}_t}{P_t}\right) \end{pmatrix},$$

- Standard Bayesian methods
- We remove sample means from data and set steady state of X to zero in estimation.

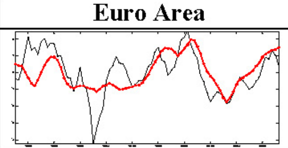
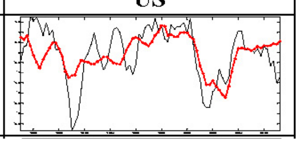
Summary of Empirical Results With Financial Frictions

- Risk shocks:
  - important source of fluctuations.
  - news on the risk shock important
- The Fisher debt-deflation channel has a substantial impact on propagation.
- Money demand and mechanism of producing inside money:
  - relatively unimportant as a source of shocks
  - modest contribution to forecast ability
- Model accounts or substantial fraction of fluctuations in term structure.
- Out-of-Sample RMSEs of the model perform well compared with BVAR and simpler models.

Risk Shocks are Important

Actual data versus what actual data would have been if there were only risk Shocks:

Figure 19. GDP Growth

Shocks	**Euro Area**	**US**
Riskiness, σ_t: whole process		

Note:
(1) as suggested by the picture, risk shocks are relatively important at the lower frequencies
(2) We find that they are the single most important source of low frequency fluctuation in the EA, and a close second (after permanent tech shocks) in the US

Table: Variance Decomposition, HP filtered data, EA

	shock	output	consumption	investment	hours	inflation	labor productivity	interest rate
Markup	σ_{λ_f}	15.02	23.05	2.63	16.37	35.74	1.40	20.46
Banking tech	σ_{x^b}	0.59	1.29	0.02	0.44	0.52	1.44	0.24
Capital tech	σ_{μ_Υ}	0.32	0.01	0.12	0.18	0.08	0.01	0.04
Money demand	σ_χ	0.02	0.06	0.00	0.02	0.00	0.00	0.00
Government	σ_g	3.26	3.11	0.00	3.34	0.87	0.21	0.48
Permanent tech	$\sigma_{\mu_z^*}$	3.72	1.16	0.24	1.42	1.07	10.29	0.72
Gamma shock	σ_γ	0.43	0.06	0.92	0.80	0.24	1.52	0.30
Temporary tech	σ_ϵ	10.54	21.68	0.49	7.46	16.10	27.52	8.56
Monetary policy	$\sigma_{\varepsilon^{policy}}$	6.22	11.27	1.01	4.14	5.40	0.10	33.15
Risk, contemp	σ_σ	2.88	0.19	5.11	6.57	0.88	13.17	1.08
Signals on risk	$\sigma_{\sigma^{signal}}$	20.09	1.81	38.09	15.96	9.22	38.24	9.80
Risk and signals	σ_σ and $\sigma_{\sigma^{signal}}$	22.96	2.00	43.20	22.53	10.09	51.41	10.88
Discount rate	σ_{ξ_c}	11.68	32.75	0.15	12.20	11.26	0.83	10.15
Marginal eff of I	σ_{ξ_i}	24.57	1.72	51.14	30.69	10.17	5.22	11.56
Price of oil	$\sigma_{\tau^{oil}}$	0.42	1.39	0.03	0.24	2.21	0.04	1.32
Long rate error	σ_{long}	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	measurement error	0.00	0.00	0.00	0.00	0.00	0.00	1.26
	inflation target	0.24	0.43	0.05	0.16	6.23	0.01	0.87
	all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table: Variance Decomposition, HP filtered data, EA

	shock	output	consumption	investment	hours	inflation	labor productivity	interest rate
Markup	σ_{λ_f}	15.02	23.05	2.63	16.37	35.74	1.40	20.46
	all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Markup shock uncomfortably important as a source of fluctuations in inflation

Table: Variance Decomposition, HP filtered data, EA

	shock	output	consumption	investment	hours	inflation	labor productivity	interest rate
Banking tech	σ_{x^b}	0.59	1.29	0.02	0.44	0.52	1.44	0.24
Money demand	σ_{χ}	0.02	0.06	0.00	0.02	0.00	0.00	0.00
	all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Banking and money demand sector not a source of shocks

Table: Variance Decomposition, HP filtered data, EA

shock	output	consumption	investment	hours	inflation	labor productivity	interest rate
σ_{γ}	0.43	0.06	0.92	0.80	0.24	1.52	0.30
σ_{σ}	2.88	0.19	5.11	6.57	0.88	13.17	1.08
$\sigma_{\sigma^{signal}}$	20.09	1.81	38.09	15.96	9.22	38.24	9.80
σ_{σ} and $\sigma_{\sigma^{signal}}$	22.96	2.00	43.20	22.53	10.09	51.41	10.88
all shocks	100.00	100.00	100.00	100.00	100.00	100.00	100.00

It's the signals! →

Table: Variance Decomposition, HP filtered data, EA

	shock	stock market	credit	spread	term structure	real M1	real M3
Markup	σ_{λ_f}	1.83	13.15	0.16	12.36	44.28	1.82
Banking tech	σ_{x^b}	0.00	0.14	0.00	0.10	5.04	42.39
Capital tech	σ_{μ_Υ}	0.18	0.07	0.03	0.07	0.03	0.02
Money demand	σ_{χ}	0.00	0.00	0.00	0.00	13.17	22.63
Government	σ_{g}	0.03	0.10	0.01	0.07	0.44	0.02
Permanent tech	$\sigma_{\mu_z^*}$	0.17	0.07	0.05	0.14	0.42	1.29
Gamma shock	σ_{γ}	5.37	25.82	1.86	0.33	0.13	0.15
Temporary tech	σ_{ϵ}	0.10	4.06	0.00	3.40	9.89	0.61
Monetary policy	$\sigma_{\varepsilon^{policy}}$	4.89	1.81	0.99	25.76	13.15	1.58
Risk, contemp	σ_{σ}	13.94	5.07	20.58	0.97	1.39	0.76
Signals on risk	$\sigma_{\sigma^{signal}}$	68.29	44.23	75.90	6.79	5.98	6.20
Risk and signals	σ_{σ} and $\sigma_{\sigma^{signal}}$	82.22	49.30	96.48	7.76	7.38	6.96
Discount rate	σ_{ξ_c}	0.02	1.72	0.02	3.99	2.46	15.40
Marginal eff of I	σ_{ξ_i}	1.90	2.54	0.27	8.77	1.18	6.17
Price of oil	$\sigma_{\tau^{oil}}$	0.14	0.94	0.05	0.56	1.87	0.15
Error in long rate	σ_{long}	0.00	0.00	0.00	36.05	0.00	0.00
	measurement error	2.89	0.19	0.02	0.32	0.21	0.02
	inflation target	0.24	0.10	0.05	0.34	0.35	0.80
	all shocks	100.00	100.00	100.00	100.00	100.00	100.00

Table: Variance Decomposition, HP filtered data, EA

	shock	stock market	credit	spread	x term structure
Gamma shock	σ_γ	5.37	25.82	1.86	0.33
Risk, contemp	σ_σ	13.94	5.07	20.58	0.97
Signals on risk	$\sigma_{\sigma^{signal}}$	68.29	44.23	75.90	6.79
Risk and signals	σ_σ and $\sigma_{\sigma^{signal}}$	82.22	49.30	96.48	7.76
	all shocks	100.00	100.00	100.00	100.00

Signal matters!

Importance of Risk Signals

News Specification on Risk and Marginal Likelihood (EA data)

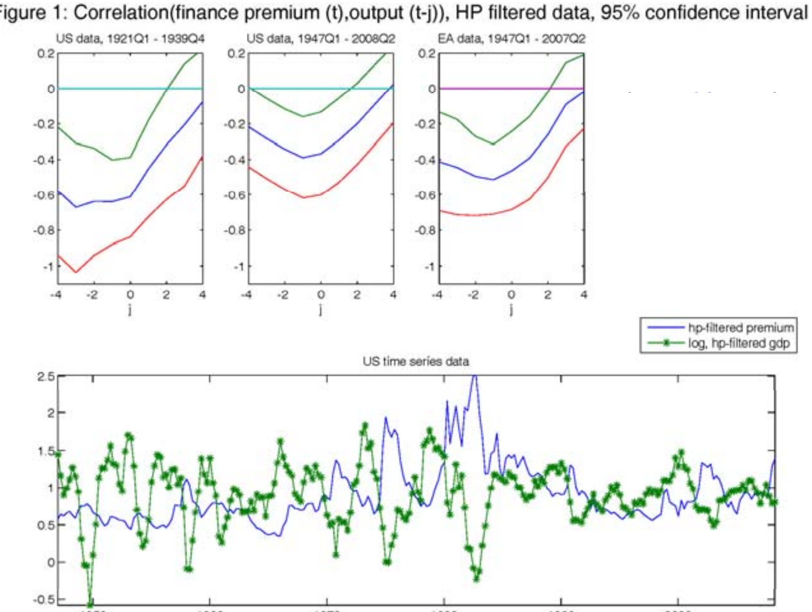
$$\hat{\sigma}_t = \rho_1 \hat{\sigma}_{t-1} + \xi^0_{t-0} + \xi^1_{t-1} + \xi^2_{t-2} + \ldots + \xi^p_{t-p}$$

p	log, marginal likelihood	odds (=exp(difference in log likelihood from baseline))
8 (baseline)	4397.487	1
6	4394.025	31
1	4325.584	∞

Why is Risk Shock so Important?

- According to the model, external finance premium is primarily risk shock.
- To look for evidence that risk might be important, look at dynamics of external finance premium and gdp.
- External finance premium is a negative leading indicator

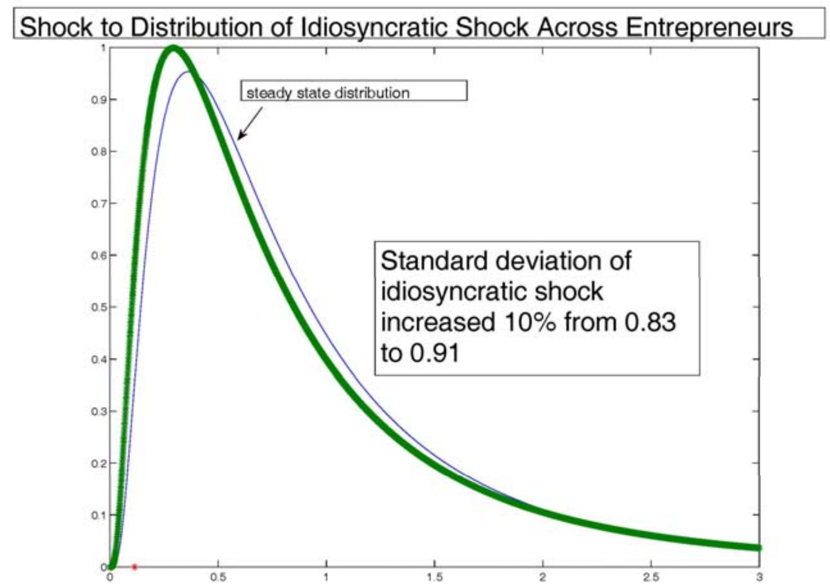
Figure 1: Correlation(finance premium (t),output (t-j)), HP filtered data, 95% confidence interval

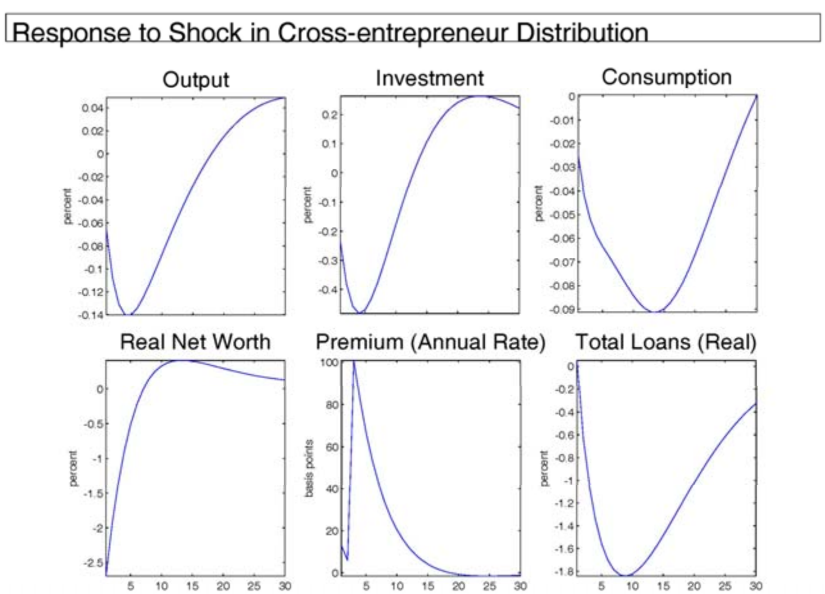


Notes: Premium is measured by the difference between the yield on the lowest rated corporate bonds (Baa) and the highest rated corporate bonds (Aaa). Bond rate data obtained from St. Louis Fed website. GDP data obtained from Balke and Gordon (1986). Filtered output data are scaled so that their standard deviation coincide with that of the premium data.

Why is Risk Shock so Important?: A second reason

- Our data set includes the stock market
  - Output, stock market, investment all procyclical (surge together in late 1990s)
  - This is predicted by risk shock.





Explaining the Slope of the Term Structure

Difference between the yield on the lowest rated corporate bonds (Baa) and the highest rated corporate bonds (Aaa)

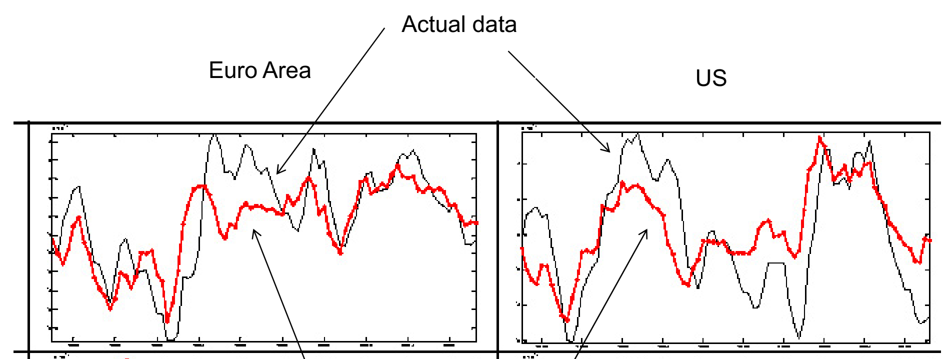
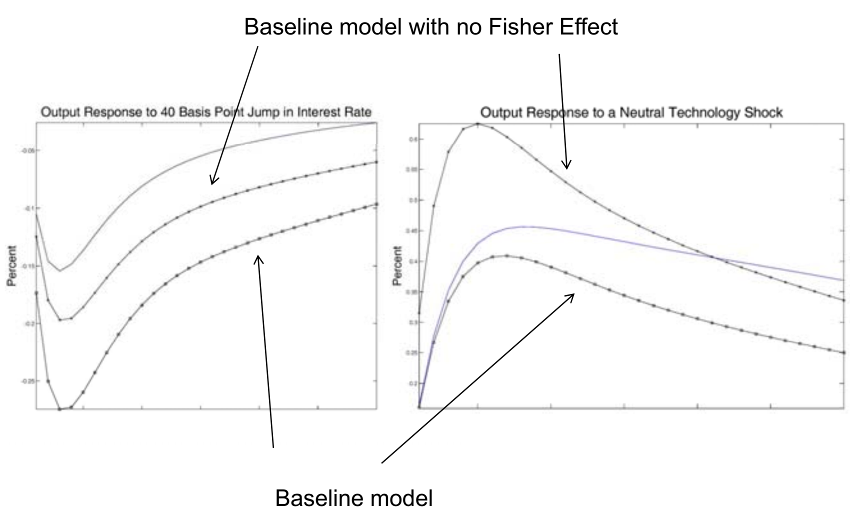


Table: Variance Decomposition, HP filtered data, EA

	shock	stock market	credit	spread	term structure (x)	real M1	real M3
Markup	σ_{λ_f} →				12.36		
Banking tech	σ_{x^b}				0.10		
Capital tech	σ_{μ_Υ}				0.07		
Money demand	σ_χ				0.00		
Government	σ_g				0.07		
Permanent tech	$\sigma_{\mu_z^*}$				0.14		
Gamma shock	σ_γ				0.33		
Temporary tech	σ_ϵ				3.40		
Monetary policy	$\sigma_{\varepsilon^{\text{policy}}}$ →				25.76		
Risk, contemp	σ_σ				0.97		
Signals on risk	$\sigma_{\sigma^{\text{signal}}}$				6.79		
Risk and signals	σ_σ and $\sigma_{\sigma^{\text{signal}}}$ →				7.76		
Discount rate	σ_{ξ_c}				3.99		
Marginal eff of I	σ_{ξ_i} →				8.77		
Price of oil	$\sigma_{\tau^{\text{oil}}}$				0.56		
Error in long rate	σ_{long} →				36.05		
	measurement error				0.32		
	inflation target				0.34		
	all shocks				100.00		

Impact of Financial Frictions on Propagation

- Effects of monetary shocks on gdp amplified by BGG financial frictions because *P* and *Y* go in same direction.
- Effects of technology shocks on gdp mitigated by BGG financial frictions because *P* and *Y* go in opposite directions.

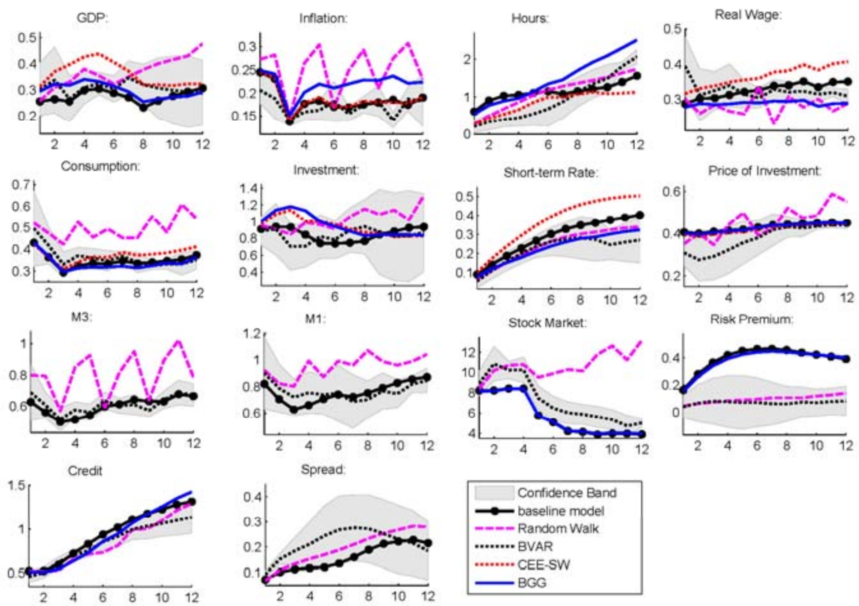


Blue line: baseline model with no financial frictions

Out of Sample RMSEs

- There is not a loss of forecasting power with the additional complications of the model.
- The model does well on everything, except the risk premium.

Figure 6.a. EA, RMSE: Confidence band represents 2 std and is centred around BVAR



Conclusion of Empirical Analysis with Financial Frictions

- Incorporating financial frictions changes inference about the sources of shocks and of propagation
  - risk shock.
  - Fisher debt deflation

- Models with financial frictions can be used to ask interesting policy questions:
  - When there is an increase in risk spreads, how should monetary policy respond?
  - How should monetary policy react to credit variables and the stock market?