Financial Factors in Business Cycles

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What We Do?

- Integrate financial factors into rather standard DSGE model
- Fit the model to EA and US data
- Evaluate credibility of model:
  - What are the shocks that drove booms and recessions?
  - How good is the model at out-of-sample forecasting?
- How important are financial factors?
  - Are they an important new source of shocks?
  - Are they important sources of propagation?

Our Finding: YES

- Lending contract are denominated in nominal terms

Model

Dynamic General Equilibrium Model:

- Core model:
  - » Christiano, Eichenbaum and Evans (2005)
- Banking system:
  - » Chari, Christiano and Eichenbaum (1995)
- Financial frictions:
  - » Bernanke, Gertler and Gilchrist (1999), as modified in CMR (2003)

We follow Smets and Wouters (2003) as regards the estimation

Model Overview

Households

- Consumption
- Labour supply / wage
- **Portfolio (currency, demand deposits, saving deposits, time deposits)**

Firms

- Monopolistic competition
- Sticky prices
- Trend growth in efficiency of labour
- **Working capital channel**

Entrepreneurs

- Ownership of capital stock
- **Own equity + Borrowing**
- Rent out capital services

Capital producers

- Transform consumption goods into investment goods
- Produce installed capital

Monetary and Fiscal Authorities

Banks

- **Assets and Liabilities**
- **Financial imperfections (agency costs)**
- **Nominal frictions (contracts in nominal terms)**

Households

- Household's Problem:

$$E_t^j \sum_{l=0}^{\infty} \beta^{l-t} \zeta_{c,t+l} \{ U_t - \upsilon \frac{\left[\left(\frac{(1+\tau^c) P_{t+l} C_{t+l}}{M_{t+l}} \right)^{(1-\chi_{t+l})\theta} \left(\frac{(1+\tau^c) P_{t+l} C_{t+l}}{D_{t+l}^h} \right)^{(1-\chi_{t+l})(1-\theta)} \left(\frac{(1+\tau^c) P_{t+l} C_{t+l}}{D_{t+l}^m} \right)^{\chi_{t+l}} \right]^{1-\sigma_q}}{1-\sigma_q} \}$$

$$\text{where } U_t = u(C_{t+l} - bC_{t+l-1}) - \psi_L \zeta_{h,t+l} \frac{h_{j,t+l}^{1+\sigma_L}}{1+\sigma_L})$$

  - Consume with habit formation
  - Monopolistic supplier of specialized labor input and sticky wages
  - Enjoy differentiated liquidity services
  - Invest also in one-period assets (backed by loan contract) and *n*-period bonds

Goods Production and Pricing

- Standard Dixit-Stiglitz aggregator for final-goods production

$$Y_t = \left[\int_0^1 Y_{jt}^{\frac{1}{\lambda_{f_t}}} dj \right]^{\lambda_{f_t}}$$

- Intermediate-goods production function

$$Y_{jt} = \epsilon_t K_{jt}^{\alpha} \left(z_t l_{jt} \right)^{1-\alpha} - \Phi z_t^* \qquad \text{with } \mu_t = \frac{z_t^*}{z_{t-1}^*}$$

- "Hybrid Phillips curve" with cost channel. In linearised form:

$$\hat{\pi}_t = \frac{\beta}{1+\beta\iota_2}\hat{\pi}_{t+1} + \frac{\iota_2}{1+\beta\iota_2}\hat{\pi}_{t-1} + \frac{\left(1-\beta\xi_p\right)\left(1-\xi_p\right)}{\xi_p\left(1+\beta\iota_2\right)}\left(\widehat{mc}_t + \hat{\lambda}_{f,t}\right)$$

$$\text{with } \widehat{mc}_t = f(\hat{w}_t, r_t^k, R_t)$$

Capital Producers

- Technology to transform final goods into investment goods:

$$I_t = Y_t \left(\Upsilon^t \mu_{\Upsilon,t} \right)$$

which implies:

$$P_t^I = P / \left(\Upsilon^t \mu_{\Upsilon,t} \right)$$

- Technology to transform investment goods into installed capital:

$$F(I_t, I_{t-1}, \zeta_{i,t}) = \left[1 - S(\zeta_{i,t} I_t / I_{t-1}) \right] I_t$$

so that

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + \left[1 - S\left(\frac{\zeta_{i,t} \, I_t}{I_{t-1}} \right) \right] I_t$$

Entrepreneurs

- Purchase new capital from capital producers K_{t+1} using internal finance and loans: CSV contract

- observe idiosyncratic productivity shock: ωK_{t+1}
- decide capital utilization rate: $u_{t+1}\omega K_{t+1}$
- bear a cost to intensity of capital utilization: $\tau_{t+1}^{o} a(u_{t+1})\omega K_{t+1}$
- rent out capital services earning a rent
- sell capital and pay off debt
- if cannot repay debt, monitored and must turn over everything
- nominal amount owed to households is not contingent on shocks realised in period t+1

Entrepreneurs

- Evolution of net worth:

$$\bar{N}_{t+1} = \gamma_t \left\{ \left(1 + R_t^k\right) Q_{\bar{K}',t-1}\bar{K}_t - \left[1 + R_t^e + \frac{\mu \int_0^{\bar{\omega}_t} \omega dF(\omega) \left(1 + R_t^k\right) Q_{\bar{K}',t-1}\bar{K}_t}{Q_{\bar{K}',t-1}\bar{K}_t - \bar{N}_t}\right] \left(Q_{\bar{K}',t-1}\bar{K}_t - \bar{N}_t\right) \right\}$$

- Standard models:

$$E_t\left(1 + R_{t+1}^k\right) = 1 + R_{t+1}^e$$

- With financial frictions, in linearised form:

$$E_t \hat{R}_{t+1}^k - \hat{R}_{t+1}^e = \alpha_1 \hat{B}_{t+1} + \alpha_2 \hat{\sigma}_t$$

Banks

- Banks are in two businesses:
  - Intermediation of loans to Entrepreneurs
  - Extension of working-capital loans to firms and provision of liquidity services (to households/firms)

Short-term Assets	**Short-term Liabilities**
- *Reserves*	- *Household demand deposits*
A_t	$D_t^h = A_t$
- *Short-term Working Capital Loans*	- *Firm demand deposits*
S_t^w	$D_t^f = S_t^w$
"Long-term" loans (to entrepreneurs)	**"Long-term" Liabilities (to households)**
B_t	T_{t-1}
	D_t^m

Banks

- Fractional-reserve system:

$$\frac{D_t^h + D_t^f + \varsigma D_t^m}{P_t} = a_t \left(\left(K_t^b\right)^{\alpha} \left(z_t l_t^b\right)^{1-\alpha} \right)^{\xi} \left(\frac{E_t^r}{P_t} \right)^{1-\xi}$$

- A spectrum of interest rates:

R_t^d

Short-term Assets	**Short-term Liabilities**
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"Long-term" loans (to entrepreneurs)	**"Long-term" Liabilities (to households)**
B_t	T_{t-1}
	D_t^m

R_t^w

R_t^m

R_t^e

Estimation

- Observable variables
  - 14 observed variables (including Monetary aggregates, premium, spread, stock market)

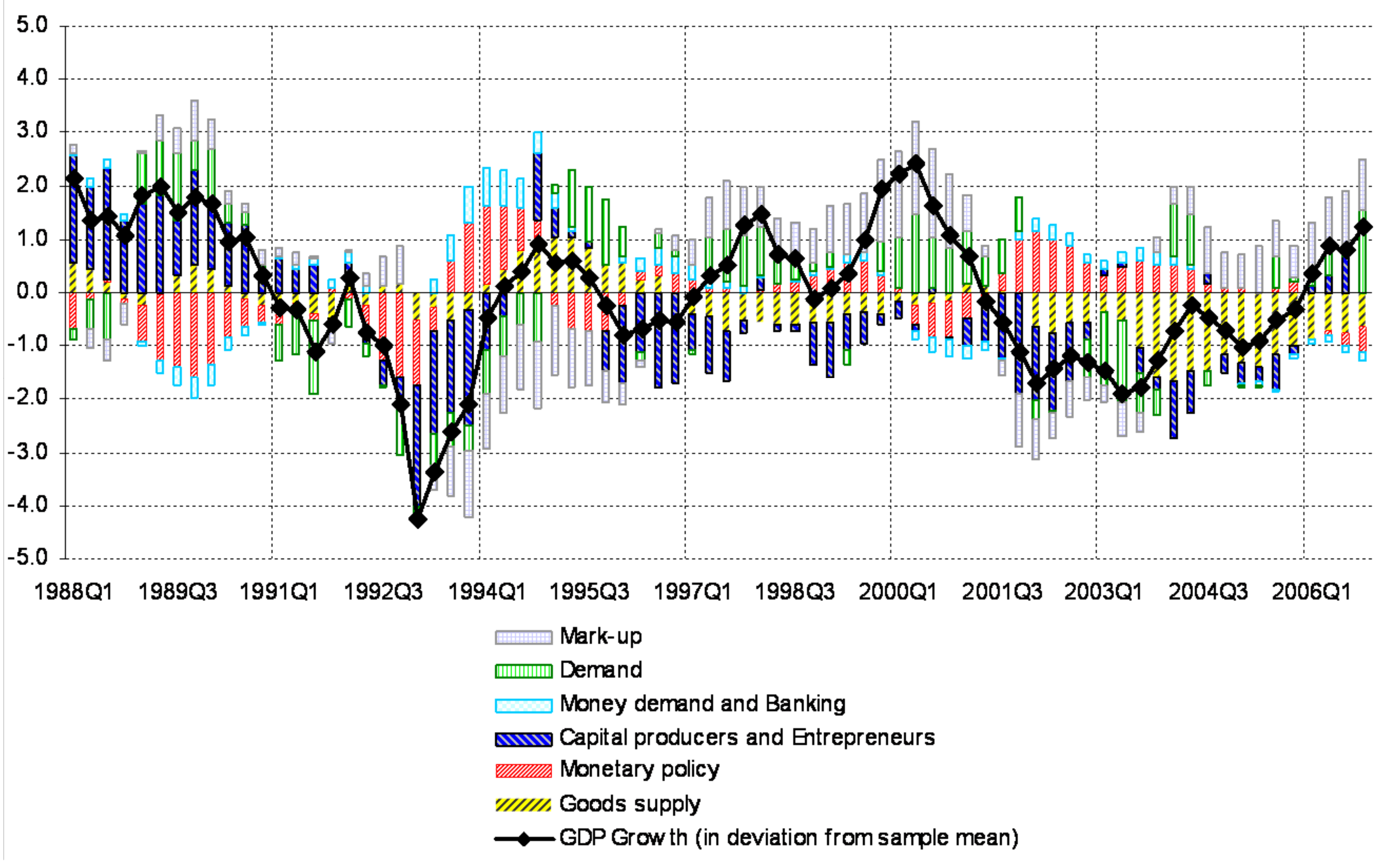
- Steady state parameters:
  - A subset set exogenously, e.g. capital depreciatior δ
  - A subset found to match steady state "great ratios," velocities and interest rates with corresponding data means, e.g.: $\beta, \ \sigma, \ \chi, \ \ldots$

- Elasticities and shock:
  - Bayesian approach: Maximum Likelihood combined with prior distributions

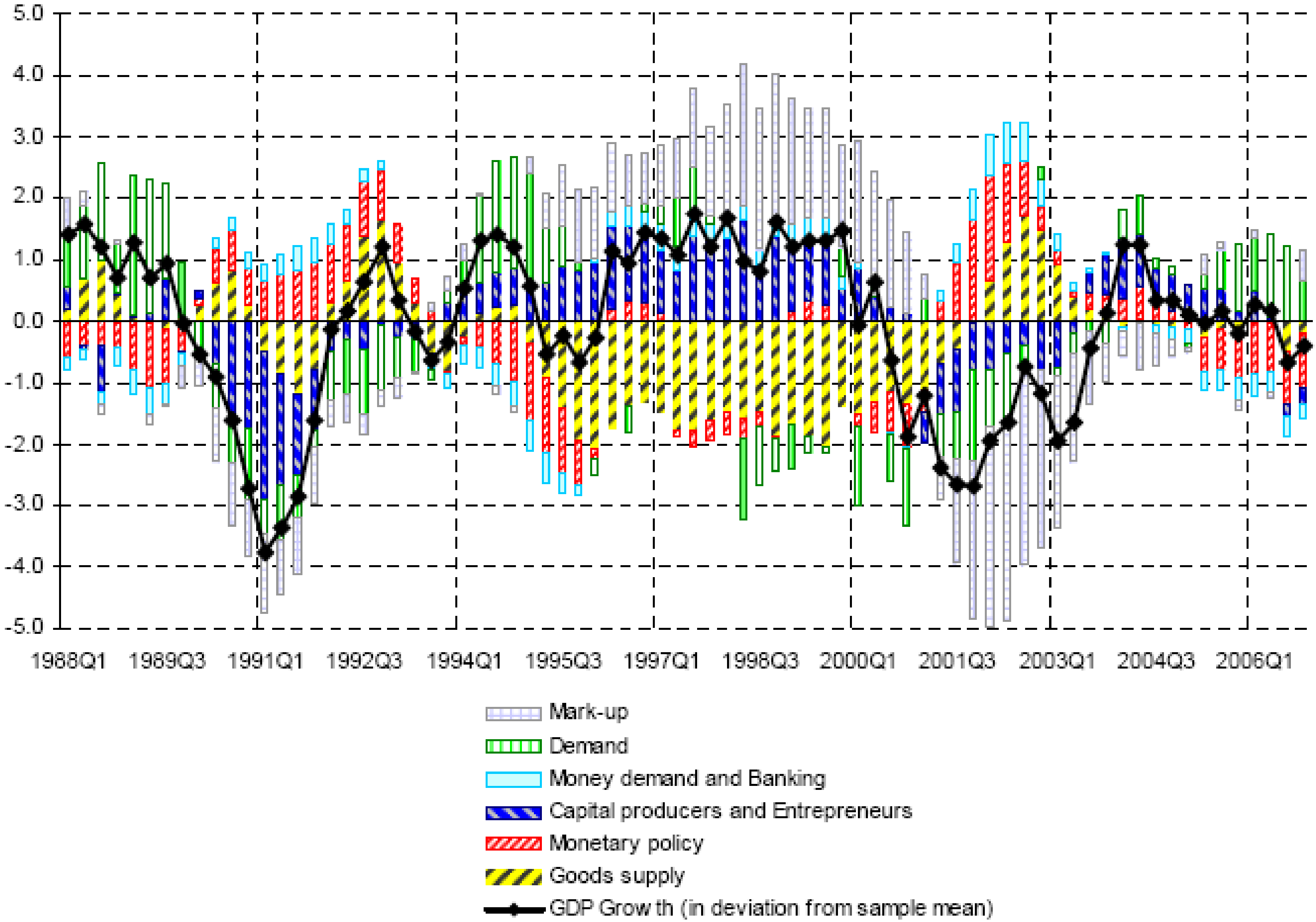
Steady State

Table 3: Money and Interest Rates. Model versus Data, EA and US									
Money	Model, EA	Data, EA	Model, US	Data, US	Interest Rates (APR)	Model, EA	Data, EA	Model, US	Data, US
M1 Velocity	3.31	3.31	6.42	6.92	Demand Deposits, R^a	0.82	0.76	0.52	n.a.
Broad Money Velocity	1.31	1.32	1.68	1.51	Saving Deposits, R^m	3.29	2.66	4.54	n.a.
Base Velocity	14.58	14.83	24.34	23.14	Long-term Assets	3.78	4.86	5.12	5.99
Currency/Base	0.69	0.69	0.75	0.75	Rate of Return on Capital, R^k	8.21	8.32	10.52	10.0
Currency/Total Deposits	0.07	0.06	0.05	0.05	Cost of External Finance, Z	6.04	4.3-6.3	7.79	7.1-8.1
(Broad Money-M1)/Base	6.75	6.76	10.69	12.16	Gross Rate on Work. Capit. Loans	4.09	n.a.	7.14	7.07
Credit Velocity	0.78	n.a.	3.16	3.25	Time Deposits, R^e	3.78	3.60	5.12	5.12

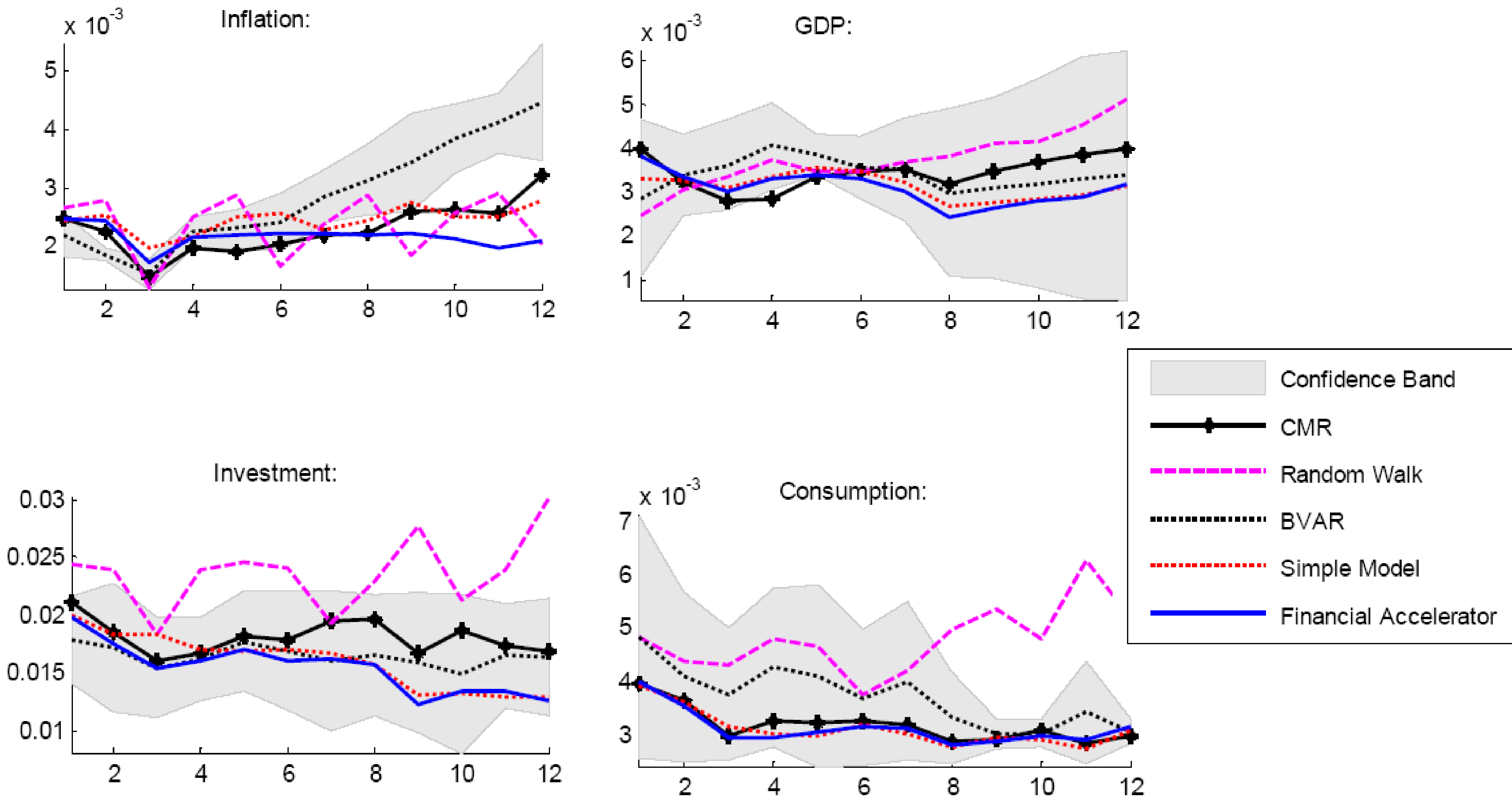
Shock Decomposition: EA GDP growth



Shock Decomposition: US GDP growth



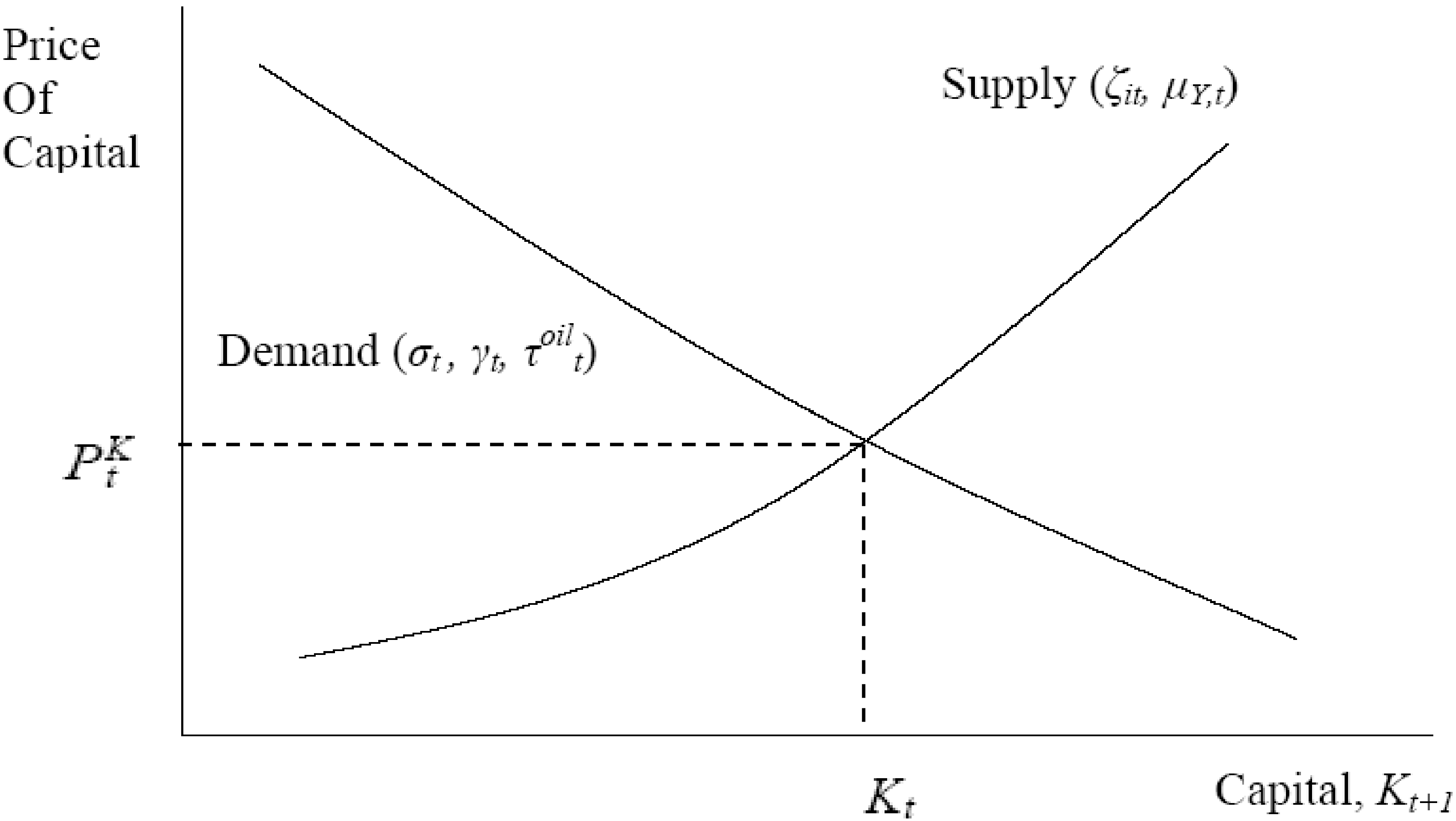
EA: Out-of-Sample Performance



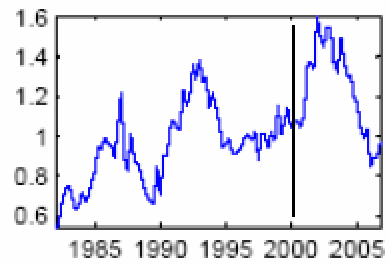
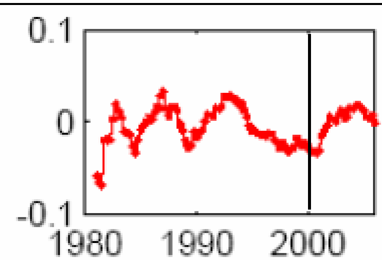
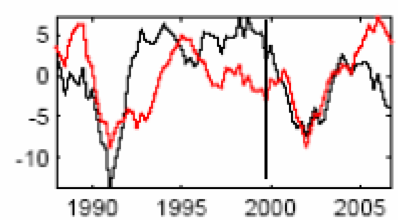
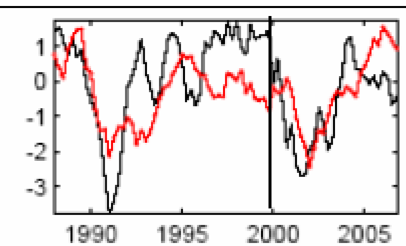
Stock Market and Shock Identification

- Stock market can help to identify shocks driving business cycle
- If capital increases at the same time that its price increases, this should come from demand and not to supply forces. This demand shock comes from our financial factors
- When we leave out financial factors and do not use stock market data, we find main driving force is favourable supply shocks in technology for constructing capital

Capital Formation



Stock Market and Shock Identification

	Simple Model
	Investment efficiency shock
Shocks	
Capital Price	
Investment	
Output	

Financial Sector

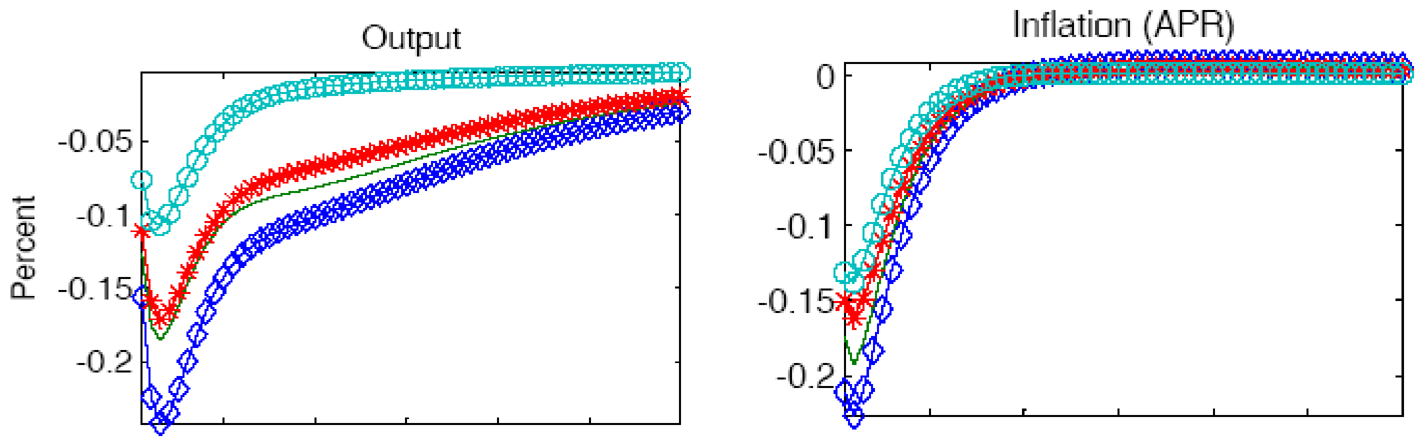
- We have argued that financial sector is an important source of shocks

- How important for propagation of non-financial shocks?
  - Nominal frictions in debt contract generate large and persistent effects. Amplification of shocks that move output and inflation in same direction. Mitigate other shocks

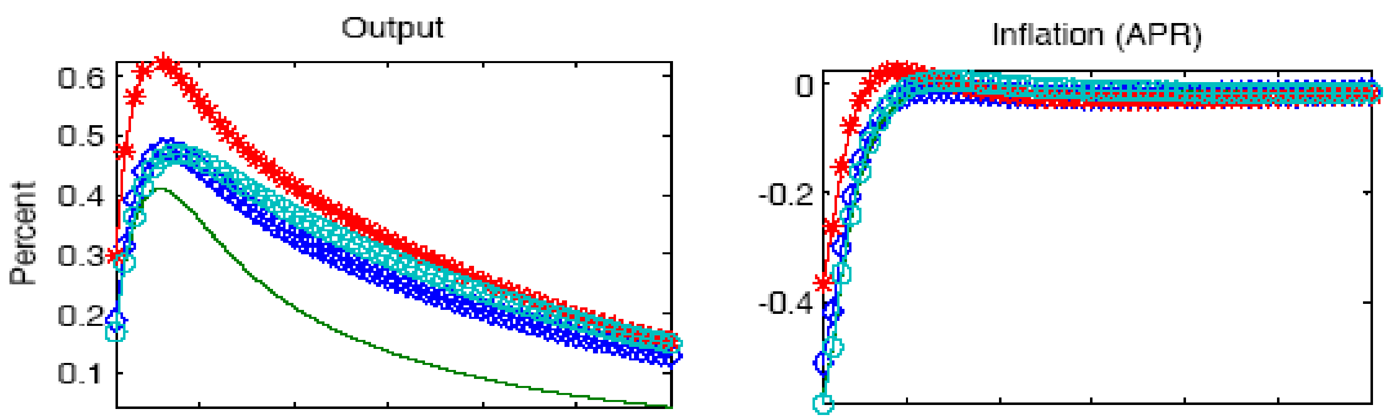
  - Banks amplify shocks

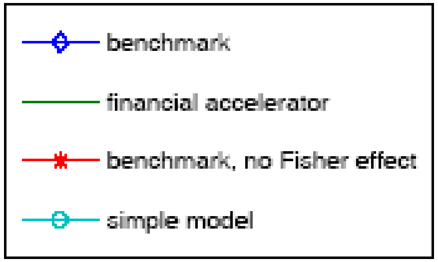
Propagation of Shocks

Impulse response to monetary policy shock



Impulse response to neutral technology shock



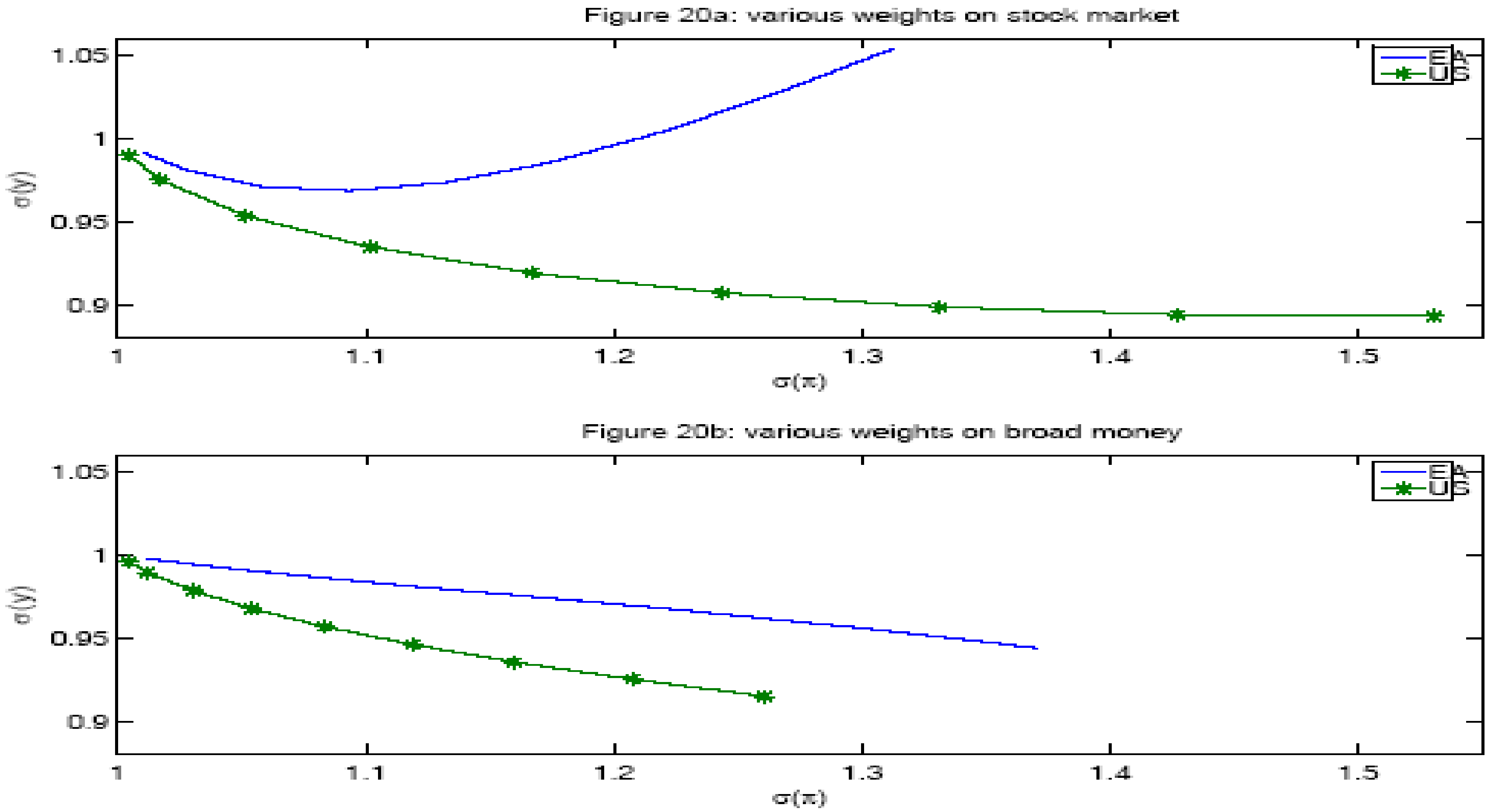


Conclusions

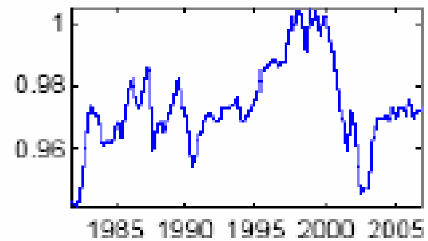
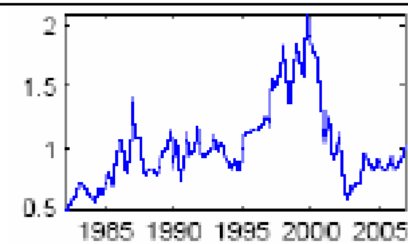
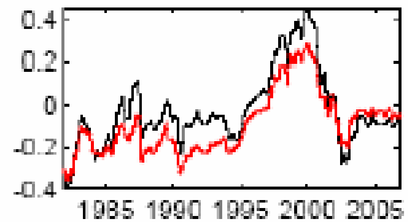
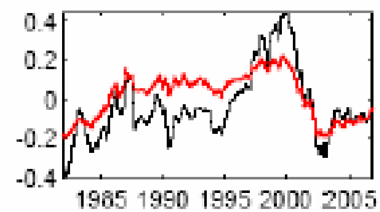
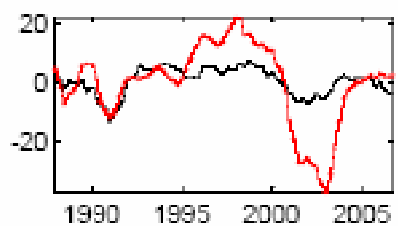
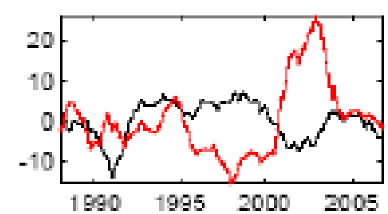
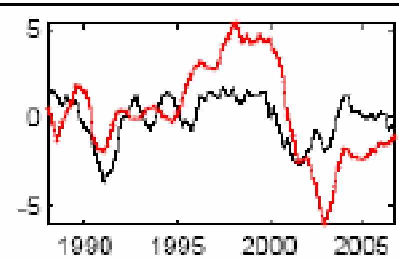
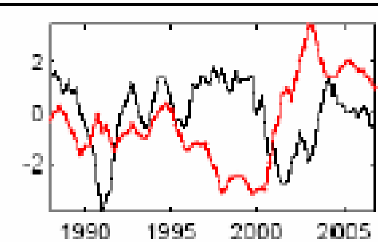
- Constructed a model that provides useful interpretation of economic fluctuations

- Financial Frictions are important
  - Source of Shocks
  - Source of Propagation

Policy Implications: Taylor Frontier



Stock Market and Shock Identification

	CMR Model Financial wealth shock	CMR Model Investment efficiency shock
Shocks		
Capital Price		
Investment		
Output		

Oil Price

- Oil price is introduced in a way similar to a simplified version of Finn (JMCB 2000) and Leduc and Sill (JME 2003)
- Define energy usage to produce capital services as

$$e_t = a(u_{t+1})\bar{K}_{t+1}, \qquad a', a'' > 0,$$

- We assume that the relative price of energy in terms of the final good is exogenously given
- The real cost of energy purchase by the jth entrepreneur is:

$$\tau^o_{t+1} a(u^j_{t+1}) \omega \bar{K}^j_{t+1}$$

- Costs of energy purchase enters resource constraint and can be understood as energy purchase from rest of the world

Estimation

- Observable variables:
  - Inflation (GDP deflator)
  - GDP
  - Consumption
  - Investment
  - Three-month nominal interest rate
  - Interest rate on demand deposits
  - Spread between 10-year bond yield and short-term nominal interest rate
  - M1
  - M3
  - Stock Market index
  - Risk premium
  - Oil price
  - Real wage
  - Hours worked
  - Relative price of investment
- Sample: 1981Q1 - 2006Q4

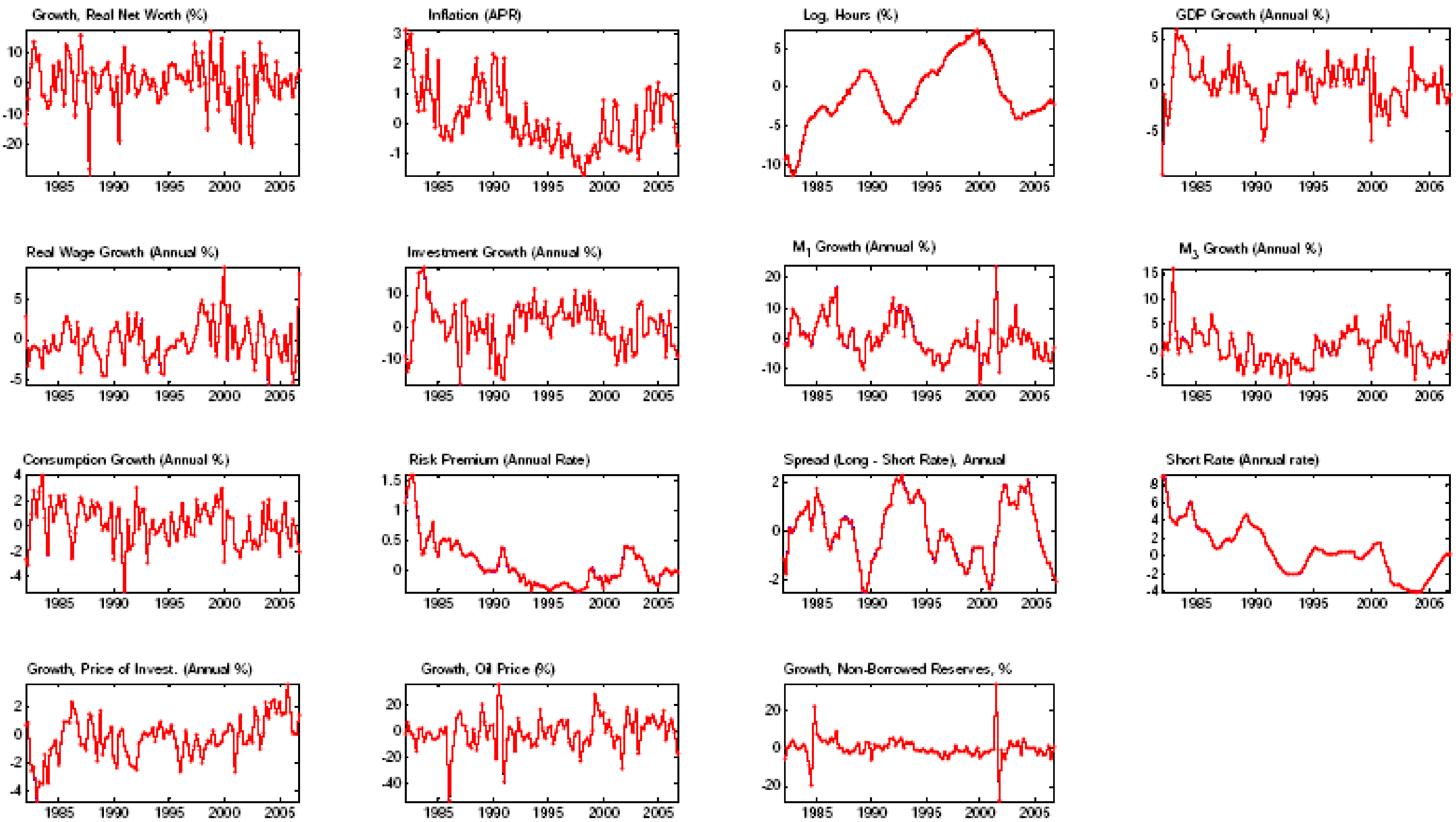
Estimation

- Shocks:
  - Demand shocks
    - Consumption preference shock
    - Government consumption
  - Goods Producing Sector
    - Permanent technology shock
    - Temporary technology shock
    - Price mark-up shock
  - Capital Production and Financing
    - Marginal efficiency of investment shock
    - Shock to the relative price of investment
    - Shock to the riskiness of entrepreneurial project
    - Financial wealth shock
    - Oil price shock
  - Banking, money demand and financial decisions
    - Banking technology shock
    - Money demand shock
    - Term premium shock
  - Monetary policy shocks
    - Temporary policy shock

Steady State

Table 2: Steady State Properties, Model versus Data, EA and US				
Variable	Model, EA	Data, EA 1998:1-2003:4	Model, US	Data, US 1998:1-2003:4
$\frac{k}{y}$	8.74	12.5[1]	6.99	10.7[2]
$\frac{i}{y}$	0.21	0.20[3]	0.22	0.25[4]
$\frac{c}{y}$	0.56	0.57	0.58	0.56
$\frac{g}{y}$	0.23	0.23	0.20	0.20
r^k	0.042		0.059	
$\frac{N}{K-N}$ ('Equity to Debt')	1.11	1.08-2.19[5]	7.67	>4.7[6]
Transfers to Entrepreneurs (as % of Goods Output)	1.64%		4.31%	
Banks Monitoring Costs (as % of Output Goods)	0.95%		0.27%	
Output Goods (in %) Lost in Entrepreneurs Turnover	0.21%		1.50%	
Percent of Aggregate Labor and Capital in Banking	0.93%		0.95%	5.9%[7]
Inflation (APR)	1.84%	1.84%[8]	2.32%	2.32%[9]

US: Two-sided Kalman filter



Parameter Estimates

		Prior			Posterior Euro area			Posterior US		
		Type	Mean	Std. dev.	Mode	Std. dev. (Hess.)	90% Prob. Interval**	Mode	Std. dev. (Hess.)	90% Prob. Interval**
ξ_p	Calvo prices	Beta	0.75* 0.375	0.05	0.7410	0.0345	0.684-0.798	0.5149	0.0384	0.452-0.578
ξ_w	Calvo wages	Beta	0.75* 0.375	0.1	0.6709	0.0372	0.610-0.732	0.7909	0.0219	0.755-0.827
ι	Weight on steady state inflation	Beta	0.5	0.15	0.8850	0.0557	0.793-0.977	0.2877	0.1111	0.105-0.470
ι_w	Weight on steady state inflation	Beta	0.5	0.15	0.3752	0.0943	0.220-0.530	0.3263	0.0987	0.164-0.489
ϑ	Weight on technology growth	Beta	0.5	0.15	0.8788	0.0511	0.795-0.963	0.9166	0.0370	0.856-0.977
S''	Investment adjust. cost	Normal	7.7	3.5	22.047	2.8924	17.29-26.80	15.537	2.2588	11.82-19.25
σ_a	Capacity utilization	Gamma	6	5	24.523	7.1772	12.72-36.33	24.858	6.2860	14.52-35.20
α_π	Weight on inflation in Taylor rule	Normal	1.75	0.1	1.8706	0.0872	1.727-2.014	1.8851	0.0874	1.741-2.029
α_y	Weight on output growth in Taylor rule	Normal	0.1	0.05	0.1128	0.0497	0.031-0.194	0.1146	0.0492	0.034-0.196
$\alpha_{\Delta\pi}$	Weight on change in infl. in Taylor rule	Normal	0.3	0.1	0.2348	0.0969	0.075-0.394	0.2116	0.0985	0.050-0.375
ρ_i	Coeff. on lagged interest rate	Beta	0.8	0.05	0.8640	0.0138	0.841-0.887	0.8844	0.0123	0.864-0.905
ρ	Banking technol. shock (x_t^b)	Beta	0.5	0.2	0.9837	0.0078	0.971-0.997	0.9871	0.0077	0.975-0.999
ρ	Bank reserve demand shock (ξ_t)**	Beta	0.5	0.2	/**	/**		0.5913	0.0990	0.428-0.754
ρ	Term premium shock (σ_t^{N})	Beta	0.5	0.2	0.8106	0.0234	0.772-0.849	0.6526	0.0583	0.557-0.748
ρ	Investm. specific shock ($\mu_{\Upsilon,t}$)	Beta	0.5	0.2	0.9667	0.0181	0.937-0.996	0.9832	0.0058	0.974-0.993
ρ	Money demand shock (χ_t)	Beta	0.5	0.2	0.9944	0.0040	0.988-0.999	0.9772	0.0125	0.957-0.998
ρ	Government consumption shock (g_t)	Beta	0.5	0.2	0.9009	0.0574	0.807-0.995	0.9194	0.0232	0.881-0.957
ρ	Persistent product. shock ($\mu_{z,t}^*$)	Beta	0.5	0.2	0.0613	0.0446	0.001-0.135	0.1603	0.0760	0.035-0.285
ρ	Transitory product. shock (ϵ_t)	Beta	0.5	0.2	0.9700	0.0158	0.944-0.996	0.9828	0.0082	0.969-0.996
ρ	Financial wealth shock (γ_t)	Beta	0.5	0.2	0.7003	0.0530	0.613-0.787	0.9373	0.0105	0.920-0.955
ρ	Riskiness shock (σ_t)	Beta	0.5	0.2	0.8080	0.0313	0.757-0.860	0.9298	0.0210	0.895-0.964
ρ	Consump. prefer. shock ($\zeta_{c,t}$)	Beta	0.5	0.2	0.9570	0.0138	0.934-0.980	0.9692	0.0060	0.959-0.979
ρ	Margin. effic. of invest. shock ($\zeta_{i,t}$)	Beta	0.5	0.2	0.5517	0.1083	0.374-0.730	0.9698	0.0059	0.960-0.980
ρ	Oil price shock (τ_t^{oil})	Beta	0.5	0.2	0.9240	0.0265	0.881-0.967	0.9439	0.0238	0.905-0.983
ρ	Price mark-up shock ($\lambda_{f,t}$)	Beta	0.5	0.2	0.9389	0.0250	0.898-0.980	0.9777	0.0112	0.959-0.996

Parameter Estimates

		Prior			Posterior Euro area			Posterior US		
		Type	Mode	Df.	Mode	Std. dev. (Hess.)	90% Prob. Interval	Mode	Std. dev. (Hess.)	90% Prob. Interval
σ	Banking technol. shock (x_t^b)	Inv. Gamma	0.01	5 d	0.0901	0.0071	0.078-0.102	0.0736	0.0058	0.064-0.083
σ	Bank reserve demand shock (ξ_t)**	Inv. Gamma	0.01	5 d	/**	/**	/**	0.0071	0.0006	0.006-0.008
σ	Term premium shock (σ_t^N)	Inv. Gamma	0.1	5 d	0.0150	0.0027	0.011-0.019	0.0305	0.0084	0.017-0.044
σ	Investm. specific shock ($\mu_{\Upsilon,t}$)	Inv. Gamma	0.003	5 d	0.0033	0.0003	0.003-0.004	0.0032	0.0002	0.003-0.004
σ	Money demand shock (χ_t)	Inv. Gamma	0.01	5 d	0.0254	0.0020	0.022-0.029	0.0187	0.0015	0.016-0.021
σ	Government consumption shock (g_t)	Inv. Gamma	0.01	5 d	0.0155	0.0012	0.014-0.017	0.0209	0.0016	0.018-0.024
σ	Persistent product. shock ($\mu_{z,t}^*$)	Inv. Gamma	0.01	5 d	0.0054	0.0005	0.005-0.006	0.0076	0.0006	0.007-0.009
σ	Transitory product. shock (ϵ_t)	Inv. Gamma	0.01	5 d	0.0043	0.0004	0.004-0.005	0.0043	0.0004	0.004-0.005
σ	Financial wealth shock (γ_t)	Inv. Gamma	0.01	5 d	0.0169	0.0024	0.013-0.021	0.0063	0.0006	0.004-0.007
σ	Riskiness shock (σ_t)	Inv. Gamma	0.01	5 d	0.0794	0.0064	0.069-0.090	0.0356	0.0031	0.031-0.041
σ	Consump. prefer. shock ($\zeta_{c,t}$)	Inv. Gamma	0.01	5 d	0.0267	0.0056	0.018-0.036	0.0364	0.0061	0.026-0.046
σ	Margin. effic. of invest. shock ($\zeta_{i,t}$)	Inv. Gamma	0.01	5 d	0.0290	0.0030	0.024-0.034	0.1572	0.0372	0.096-0.218
σ	Oil price shock (τ_t^{oil})	Inv. Gamma	0.1	5 d	0.1550	0.0119	0.135-0.175	0.1317	0.0099	0.115-0.148
σ	Monetary policy shock (ε_t)	Inv. Gamma	0.25	5 d	0.4644	0.0370	0.404-0.525	0.4782	0.0374	0.417-0.540
σ	Price markup shock ($\lambda_{f,t}$)	Inv. Gamma	0.01	5 d	0.0110	0.0021	0.007-0.014	0.0075	0.0008	0.006-0.009

Parameter Estimates

Figure 1: Priors and Posteriors (US - thick line, EA - thin line)