Monetary Policy with Heterogeneous Agents

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June 24-25, 2013

CIGS Conference on Macroeconomic Theory and Policy 2013
Advances in Economic Theory and Measurement

Motivation

1. Theoretical:
   - The redistribution effects of monetary policy have long been recognized.
   - Sizable literature on heterogeneous effects of fiscal policy, relatively limited on monetary policy, especially with RBC/DSGE model with nominal frictions, central banks' policy workhorse.
   - Our study is intended to fill this gap.

2. Empirical:
   - A recent study by Coibion et al. (2012) (CGKS) found that a contractionary monetary policy shock ($R \uparrow$) increases inequality of income and consumption.
   - Income composition channel
     $\leftrightarrow$ Portfolio channel (Doepke and Schneider (2006a,b))

What We Do

1. We extend the standard RBC/DSGE model by introducing:
   1. Market incompleteness (Bewley-Aiyagari-Huggett)
   2. Nominal frictions (Rotemberg cost of nominal price adjustment)
   3. Labor market frictions (Mortensen-Pissarides' search frictions)

2. We investigate:
   1. Heterogeneous effects of monetary policy shocks.
      - Income, consumption, welfare.
      - Are model implications consistent with CGKS?
   2. Heterogeneous welfare effects of monetary policy rule.
      - (Future) Optimal simple monetary policy rule.

Main Findings

1. Consistent with empirical findings of CGKS, our model implies that a contractionary monetary policy shock increases inequality of households' income and consumption.

2. Mainly through the income composition channel.
   - Labor income ($\downarrow$ when R $\uparrow$) vs. financial income ($\uparrow$ when R $\uparrow$).

3. Countercyclical monetary policy has redistribution effects.
   - Average welfare effect is larger in HA economy than RA economy.

4. Long-run? Lower precautionary savings hurt everybody.

Related Literature

1. Empirical work:
   - Monetary policy shocks dampen aggregate activity: Christiano et al. (2005), Romer and Romer (2004).
   - Monetary policy shocks increase various inequality measures: Coibion et al. (2012).
   - Sizable savings redistribution due to surprise inflation: Doepke and Schneider (2006b).
   - Earnings inequality widens sharply in recessions, linked to unemployment: Heathcote et al. (2009).
2. Theoretical work:
   - DSGE models with nominal and labor market frictions: Galí (2010), Trigari (2009), Walsh (2005), Kuester (2010).
   - Real effects of redistribution of wealth due to surprise inflation: Doepke and Schneider (2006a), Meh et al. (2010).
   - Heterogeneous effects of steady-state inflation: Erosa and Ventura (2002), Albanesi (2007).
   - Heterogeneous-agent model with labor market frictions: Nakajima (2012), Krusell et al. (2010).

Model: Agents

- Households
  - Infinitely-lived.
  - Subject to idiosyncratic unemployment and productivity shocks.
  - Self-insurance, using shares of the mutual funds.
  - Borrowing constrained.
  - Heterogeneous with respect to (e, s, a).
- Representative Mutual Funds
  - Hold equity of all firms, and nominal bonds.
  - Shares are held by households.
  - Profits from firms are distributed to households as dividends.
- Central Bank
  - Determine interest rate of nominal bonds.
  - Taylor rule with: ρ_{Π}, ρ_{u}, and monetary policy shocks.
- Government
  - Run unemployment insurance program.
  - Adjust τ to keep period-by-period budget balance.

Model: Firms

- Labor Firm (Mortensen-Pissarides)
  - Post a vacancy and hire a worker (search friction).
  - Rent out labor services in a competitive market.
  - Separate at probability λ.
- Capital Firm
  - Make investment and accumulate capital.
  - Rent out capital in a competitive market.
- Intermediate Good Firm (NK-DSGE)
  - Use capital and labor to produce intermediate goods.
  - Subject to aggregate TFP shocks.
  - Sell intermediate goods to final good firms.
  - Monopolistically competitive.
  - Subject to quadratic nominal price adjustment cost.
- Final Good Firm (NK-DSGE)
  - Use differentiated intermediate goods to produce final goods.
  - Final goods are used for consumption and investment.

Model: Employed Household

$$W(X, 1, s, a) = \max_{c, a' \geq 0} u(c) +$$
$$\beta \mathbb{E}[(1 - \lambda + \lambda f(X)) W(X', 1, s', a')$$
$$+ \lambda(1 - f(X)) W(X', 0, s', a')] \quad (1)$$

subject to:

$$c + p_a(X) a' = (p_a(X) + d_a(X)) a + w(X) s (1 - \tau(X)) \quad (2)$$

- $(p_a(X), d_a(X))$: (price, dividends) of a share.
- $w(X)$: real wage.
- λ: separation rate.
- $f(X)$: job-finding rate.
- $\tau(X)$: proportional UI tax rate.

Model: Unemployed Household

$$W(X, 0, s, a) = \max_{c, a' \geq 0} u(c) + \beta \mathbb{E}[f(X)\, W(X', 1, s', a') + (1 - f(X))\, W(X', 0, s', a')] \quad (3)$$

subject to:

$$c + p_a(X)a' = (p_a(X) + d_a(X))a + bs \quad (4)$$

- b: UI benefits.

Mutual Fund

- We abstract from households' portfolio choice problem and assume households own shares of the representative mutual fund (MF).
- Price of a share $= p_a$.
- The MFs own and trade with each other:
  - Equity of capital, labor, and final and intermediate good firms.
  - Nominally risk-free one-period bonds (zero net supply in eqm).
- The central bank controls the nominal return on the bonds.
- Each period, the MFs pay the profits as dividends $(= d_a)$ to households, in proportion to share holdings.

Central Bank

The central bank determines the risk-free nominal rate R following a Taylor rule:

$$\log\left(\frac{R}{\overline{R}}\right) = \rho_{\Pi} \log\left(\frac{\Pi}{\overline{\Pi}}\right) - \rho_{u}\left(\frac{u}{\overline{u}}\right) + D \tag{5}$$

$$\log(D') = \rho_{D} \log(D) + \epsilon_{D} \text{ , where } \epsilon_{D} \text{ is i.i.d. } N(0, \sigma_{D}^{2}) \tag{6}$$

- D: Monetary policy shock (tighter/looser policy than usual).
- ρ_{Π}: Systematic response of policy rate, for inflation stabilization.
- ρ_{u}: Systematic response of policy rate, for unemployment stabilization (Blanchard and Galí (2010)).

Government

- The government runs the UI program.
- τ is adjusted to satisfy the budget constraint:

$$0 = \tau \int_{\mathcal{M}} \mathbb{1}_{e=1} ws \; d\mu - \int_{\mathcal{M}} \mathbb{1}_{e=0} bs \; d\mu \tag{7}$$

Model: Labor Firm

$$J_L(X,s) = (h(X) - w(X))s + \mathbb{E}Q(X,X')(1-\lambda)J_L(X',s') \tag{8}$$

$$\kappa = \frac{M(U(X)+\lambda N(X), V(X))}{V(X)}\mathbb{E}J_L(X,s) \tag{9}$$

- $V(X)$ is determined by the zero profit condition.
- $h(X)$: rental cost of labor per efficiency unit.
- $Q(X,X')$: Aggregate discount factor.
- κ: vacancy posting cost.
- $M(U+\lambda N, V)$: matching function.
- Ad-hoc wage function is assumed for now ($\epsilon_w = 0.45$):

$$\log(w(X)) = \log(\overline{w}) + \epsilon_w(\log(y(X)) - \log(\overline{y}))$$

Capital Firm

$$J_K(X,k) = \max_{v,i,k'} \left\{ r(X)kv - i + \mathbb{E}Q(X,X')J_K(X',k') \right\} \tag{10}$$

subject to:

$$k' = (1-\delta(v))k + \zeta\left(\frac{i}{k}\right)k \tag{11}$$

- k: capital stock.
- i: investment.
- v: capacity utilization (for smoother response of marginal costs).
- $r(X)$: rental rate of capital.
- $\delta(v)$: depreciation rate (increasing in v).
- $\zeta(.)$: investment adjustment cost function.

Intermediate Good Firm

$$J_I(X, P_{j,-1}) = \max_{P_j, \ell_j, k_j} y_j(X, P_j) \left(\frac{P_j}{P} - \frac{\phi_\Pi}{2} \left(\frac{P_j}{P_{j,-1}} - \overline{\Pi} \right)^2 \right)$$
$$- r(X) v(X) k_j - h(X) \ell_j + \mathbb{E} Q(X, X') J_I(X', P_j) \quad (12)$$

subject to:

$$y_j = Z k_j^{\theta} \ell_j^{1-\theta} \quad (13)$$

$$log(Z') = \rho_Z log(Z) + \epsilon_Z, \text{ where } \epsilon_Z \text{ is i.i.d. } N(0, \sigma_Z^2) \quad (14)$$

- Monopolistically competitive, facing quadratic price adj cost.
- P_j: price of a good j.
- P: price of a final good (aggregate price level).
- (k_j, ℓ_j): capital and labor used for producing good j.
- ϕ_Π: parameter for quadratic price adjustment cost.

Final Good Firm

$$\max_{y, y_j \in [0,1]} P(X)y - \int_0^1 P_j y_j \, dj \tag{15}$$

subject to:

$$y = \left(\int_0^1 y_j^{\frac{\epsilon-1}{\epsilon}} \, dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{16}$$

- Dixit-Stiglitz production function with intermediate goods j.
- Chooses output of final goods, y, and inputs y_j.
- Yields the demand schedule for each intermediate good $y_j(X, P_j)$.

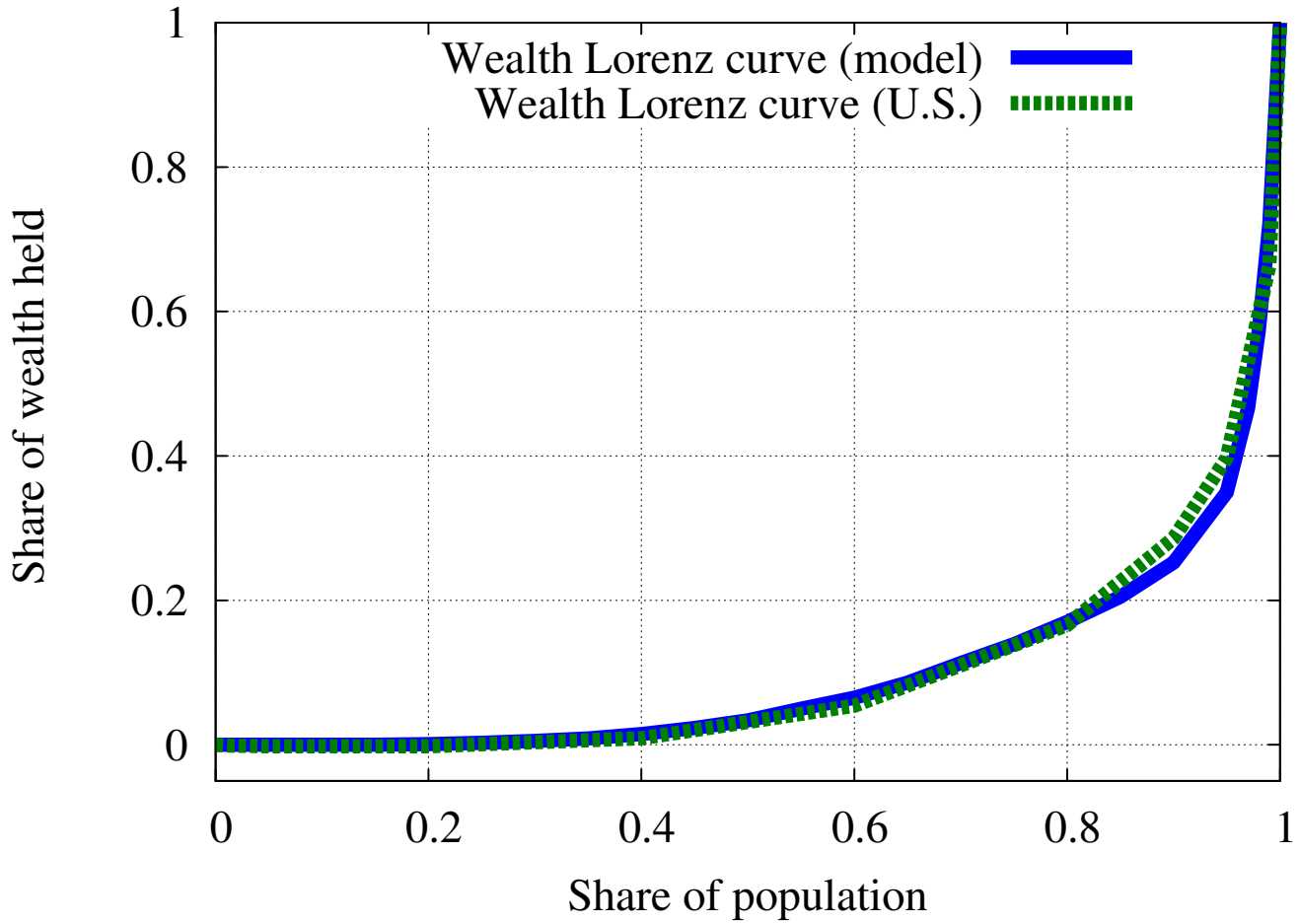
Equilibrium

Definition (Recursive Equilibrium)

1. Optimality of decisions of households and all firms.
2. Dividends d_a are consistent with the budget constraint of the representative mutual fund.
3. Formula for the aggregate discount factor is exogenously given.
4. Wage function is exogenously given.
5. τ satisfies the government budget constraint.
6. R follows the Taylor rule.
7. Consistency of aggregate laws of motions.
8. All markets clear.
9. Symmetry across all intermediate goods: $P_j = P_{j'} (= P)$.

Calibration: Wealth Distribution

- Parameters for individual productivity shocks are calibrated to match the observed inequality of income and wealth (SCF).
- 10% of households are borrowing-constrained.
  (lower bound of empirical estimates)



Business Cycle Statistics: Output and its Components

	SD%	SD/SD(Y)	Corr with Y	AR(1)
US: 1984Q1-2008Q3				
Output (Y)	1.36	1.00	1.00	0.92
Consumption	0.77	0.56	0.84	0.82
Investment	4.77	3.49	0.93	0.85
Capacity utilization	1.87	1.36	0.75	0.91
Baseline model				
Output (Y)	1.37	1.00	1.00	0.64
Consumption	0.55	0.40	0.96	0.74
Investment	4.18	3.05	0.99	0.73
Capacity utilization	1.00	0.73	0.78	0.28

- Model replicates cyclical properties of output and its components.
- Consumption: less volatile than output and procyclical.
- Investment: much more volatile than output and procyclical.

Business Cycle Statistics: Labor Market

	SD%	SD/SD(Y)	Corr with Y	AR(1)
US: 1984Q1-2008Q3				
Employment	0.50	0.36	0.81	0.94
Unemployment	8.48	6.20	-0.84	0.94
Vacancies	10.05	7.34	0.89	0.91
Job finding rate	5.84	4.27	0.75	0.78
Baseline model				
Employment	0.57	0.42	0.93	0.68
Unemployment	9.63	7.03	-0.92	0.67
Vacancies	10.62	7.75	0.83	0.18
Job finding rate	4.64	3.36	0.91	0.42

- Model replicates cyclical properties of labor market data.
- Large volatility of unemployment and vacancies replicated.
- Countercyclical unemployment and procyclical vacancies.

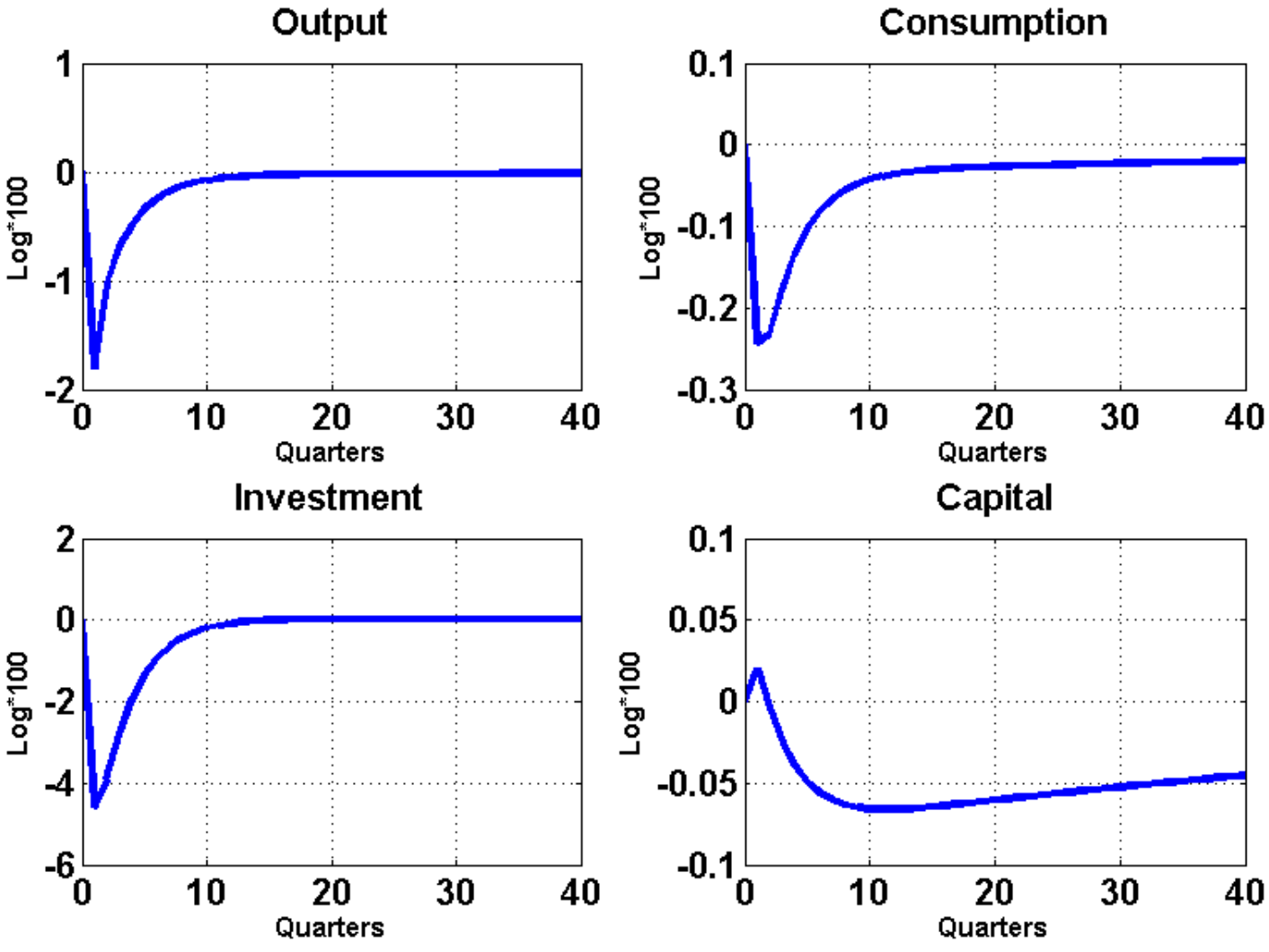
Business Cycle Statistics: Productivity and Prices

	SD%	SD/SD(Y)	Corr with Y	AR(1)
US: 1984Q1-2008Q3				
Output per worker	0.93	0.68	0.89	0.84
Wage per worker	0.89	0.65	0.49	0.84
Nominal interest rate	0.29	0.21	0.60	0.92
Inflation	0.17	0.12	0.22	0.16
Baseline model				
Output per worker	0.86	0.63	0.97	0.61
Wage per worker	0.62	0.45	1.00	0.64
Nominal interest rate	0.05	0.04	0.09	0.29
Inflation	0.09	0.07	0.27	0.40

- Model succeeds in generating moderately volatile and procyclical productivity and wage.
- Not-so-volatile nominal interest rate and inflation.
  $\rightarrow$ Typical for a model with only two shocks.

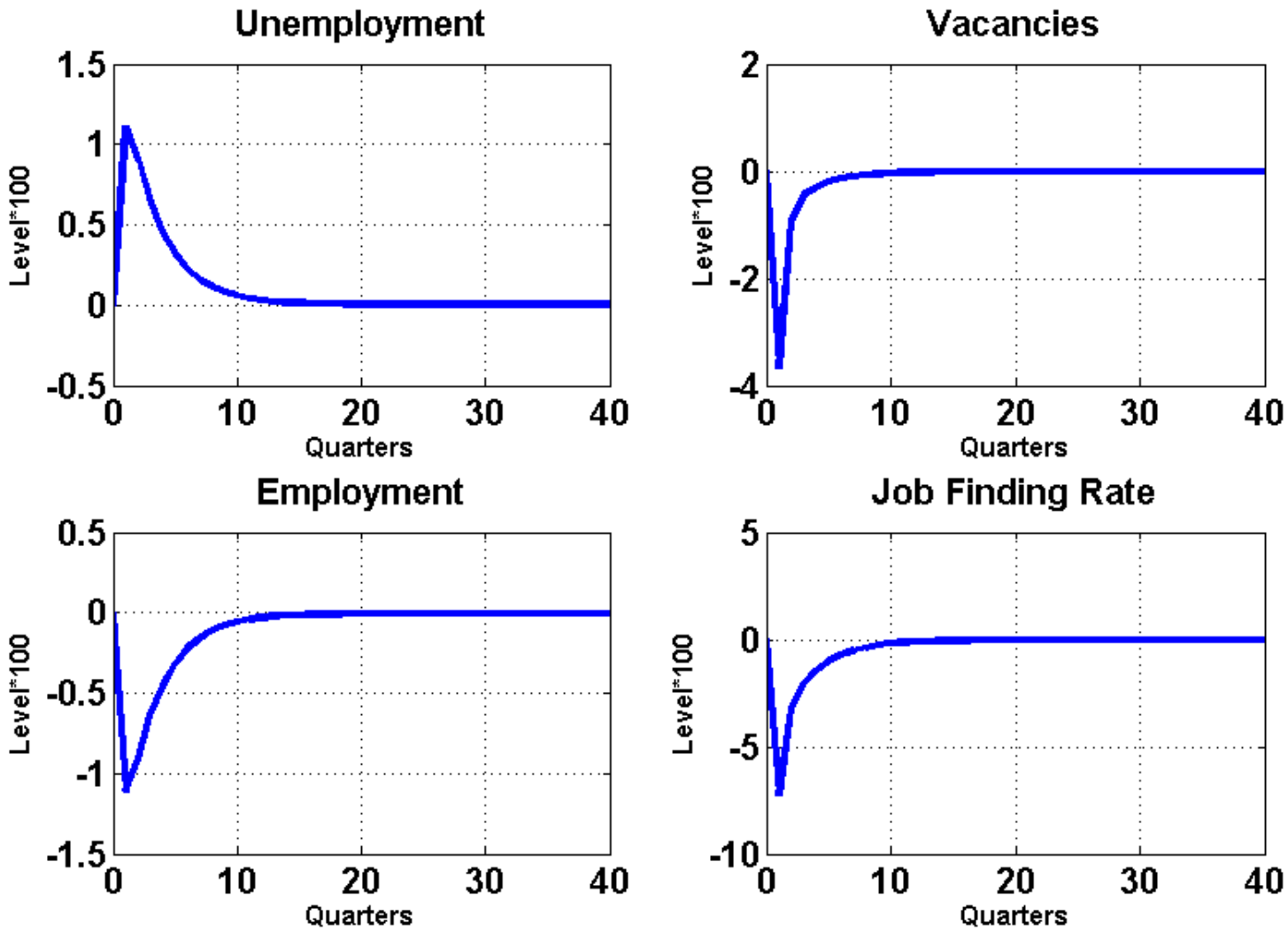
Impulse Response to MP Shock: Output

- 25bps (annual 1%) increase in the policy rate ($\times 4$ S.D.!)
- Y (-1.8%), C and I fall (front-loaded).



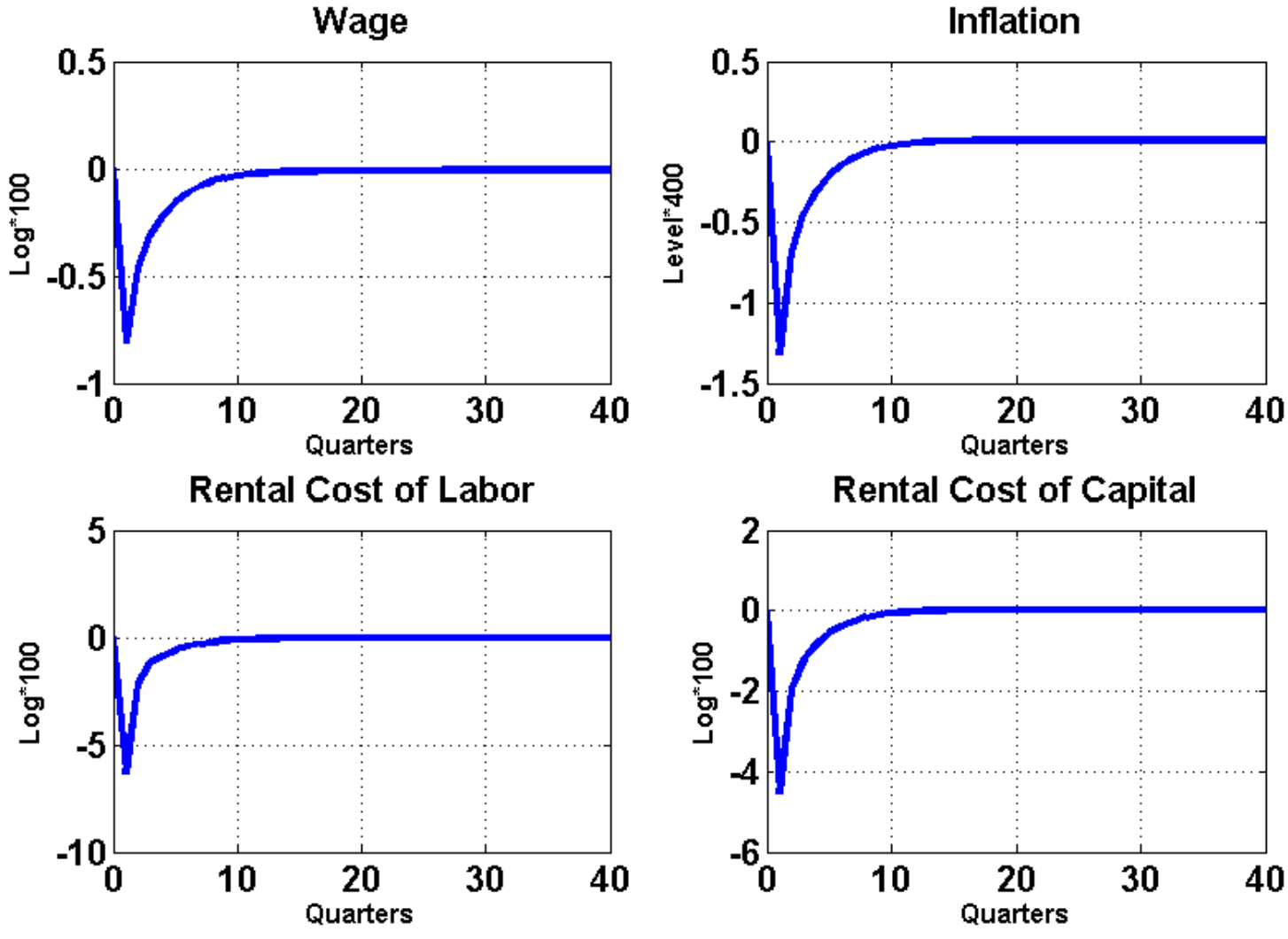
Impulse Response to MP Shock: Labor Market

- Sharp increase in unemployment rate (+1.1%).
  ← Large shock and strong amplification.



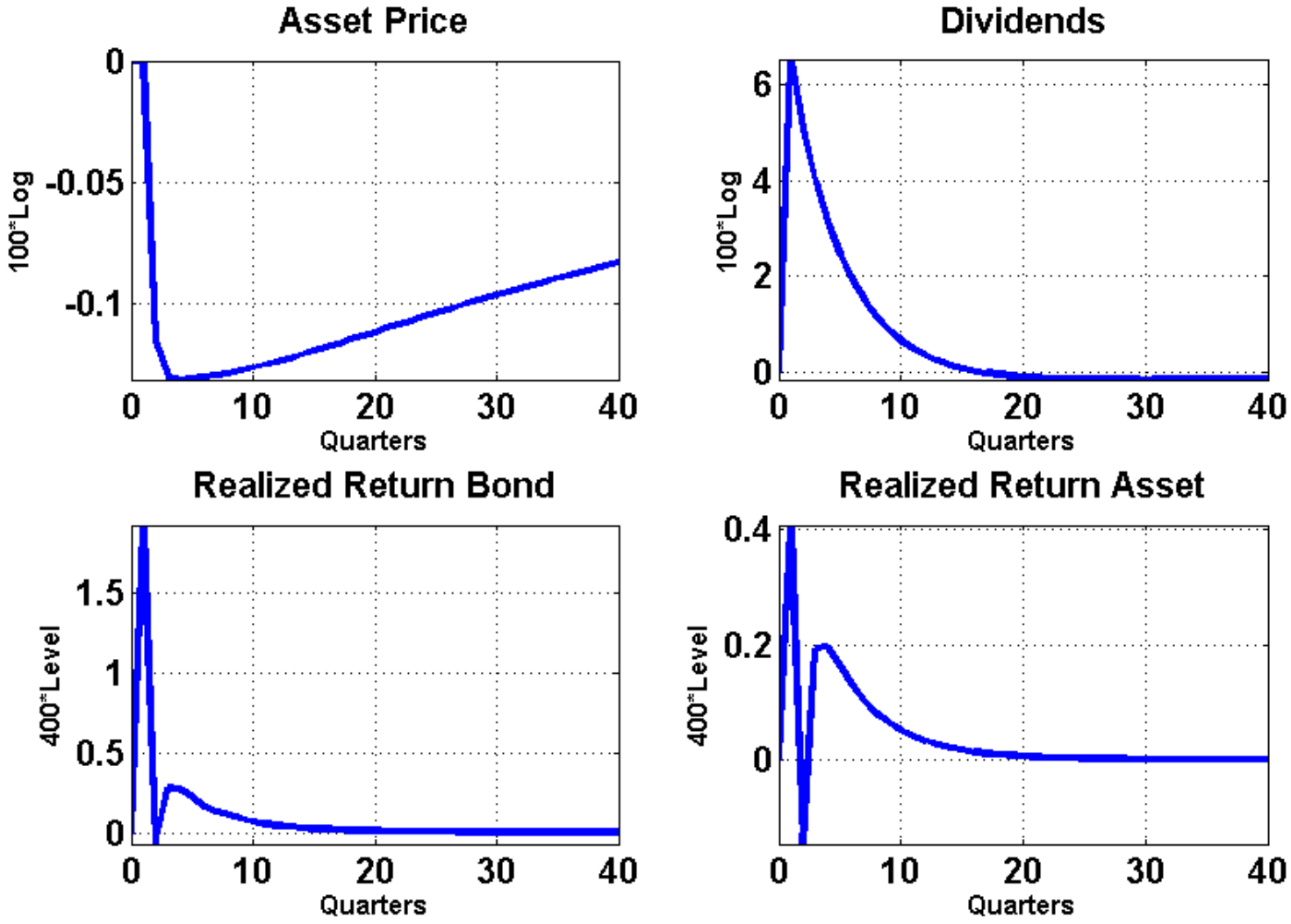
Impulse Response to MP Shock: Prices

- Inflation and rental prices of factors decline as demand weakens.



Impulse Response to MP Shock: Financial Markets

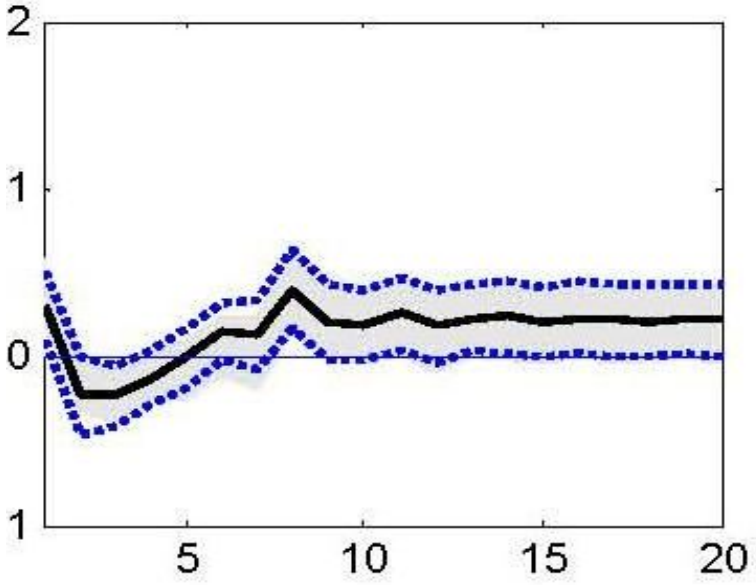
- Discount rate increases $\rightarrow$ Front-loading of dividends.
  $\rightarrow$ Financial income increases in the short-run.
- Share price declines, reflecting lower dividends in the long-run.

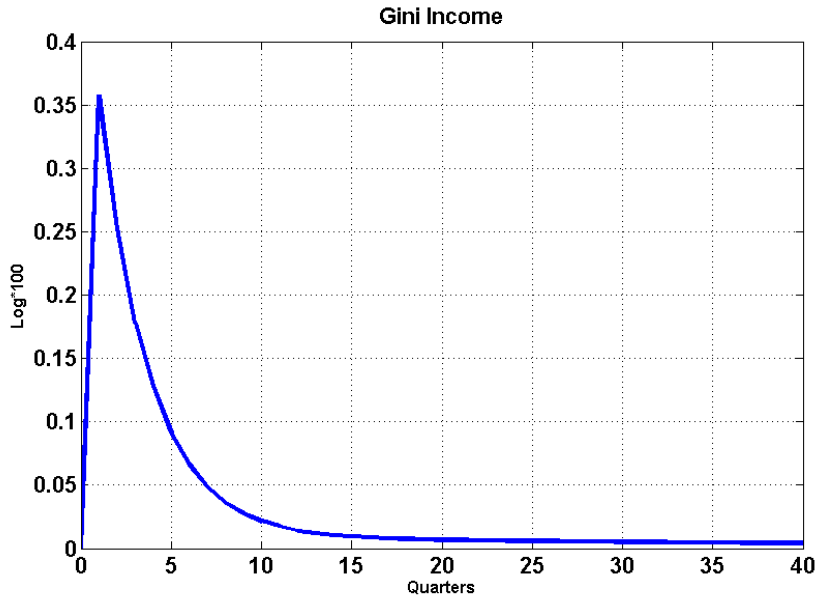


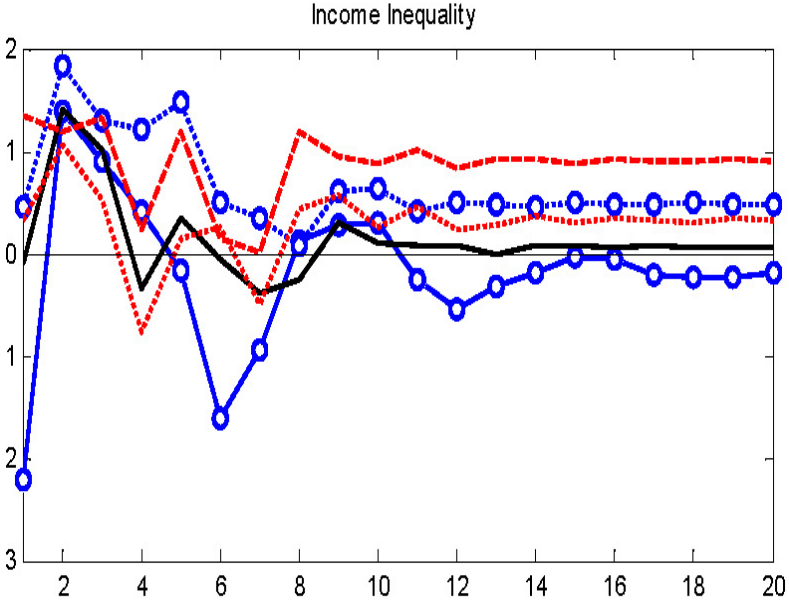
Result 1: Impulse Response to MP Shock (+1%)

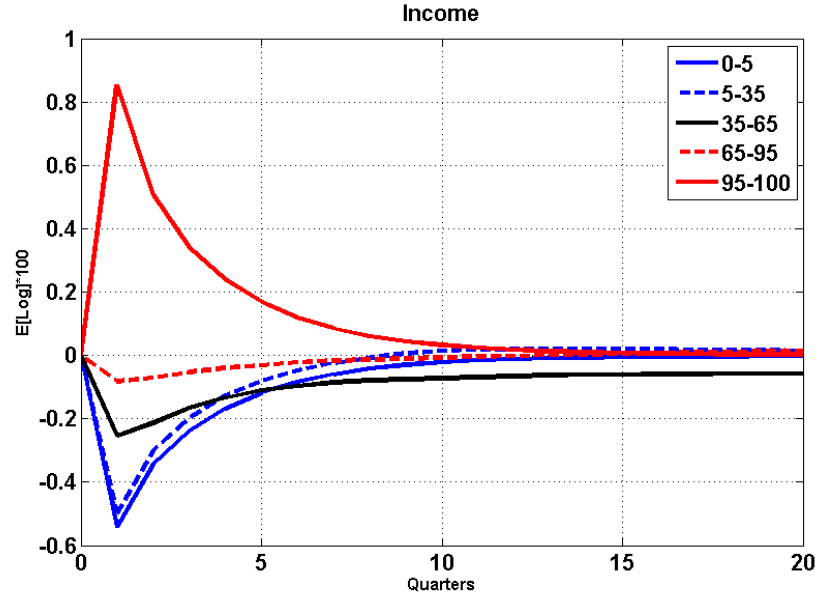
- Income inequality rises in response to $R \uparrow$.
  - Income composition channel.
  - Wealth-rich households' income rises due to a spike in dividends.
  - Wealth-poor households' income declines from lower labor income. (lower wage and higher unemployment)
- Consumption inequality rises in response to $R \uparrow$.
  - Rising income inequality.
  - Borrowing constraint for lower-income households.
- Consistent with CGKS.

Impulse Response to MP Shock (+1%): Income Inequality





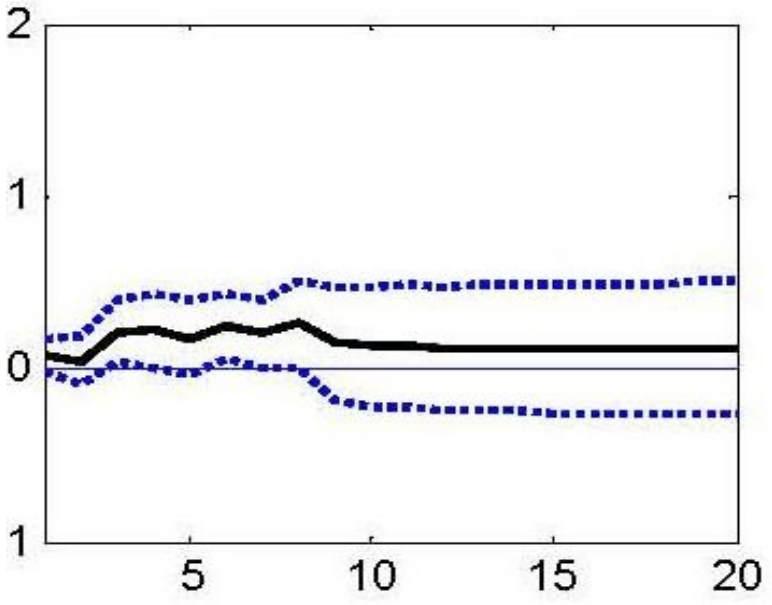


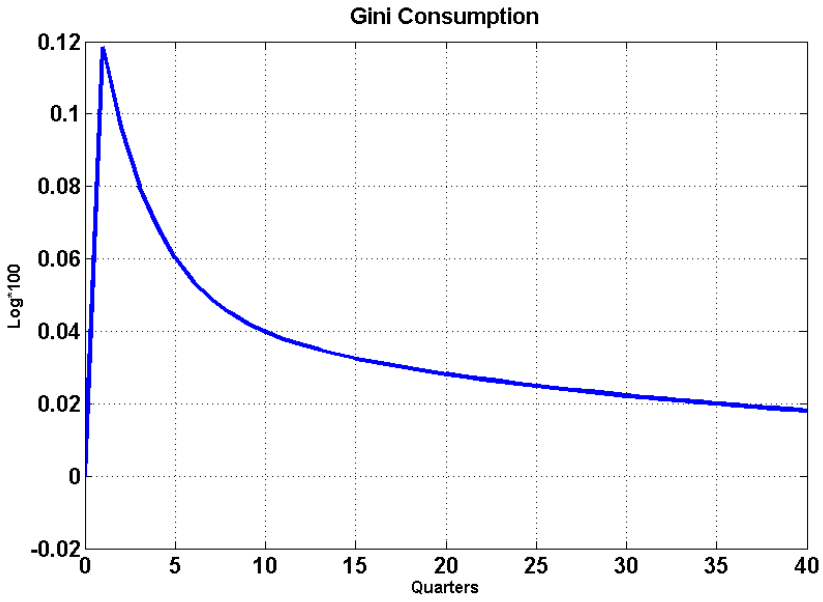


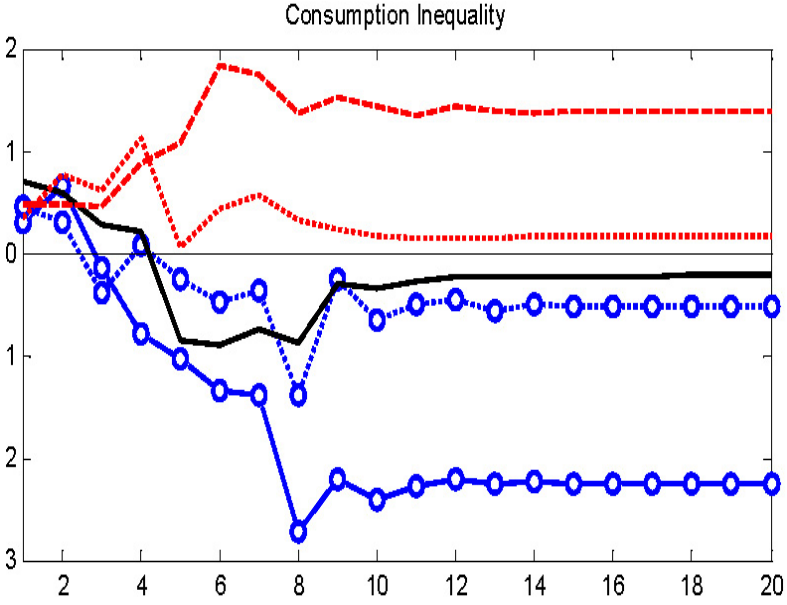
CGKS

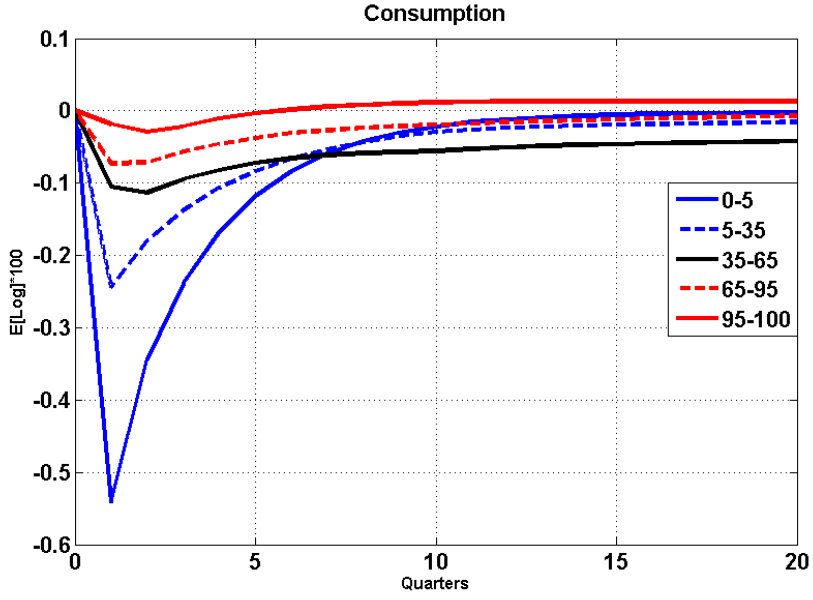
Model

Impulse Response to MP Shock (+1%): Cons Inequality





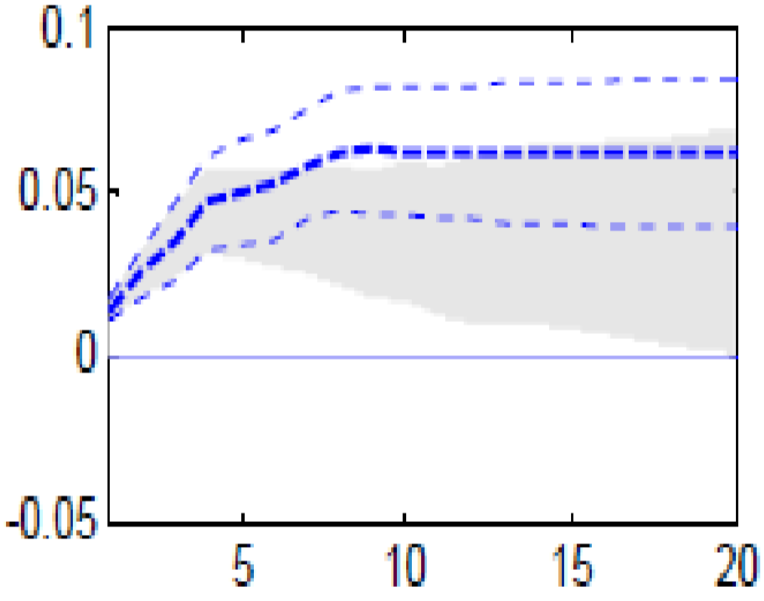




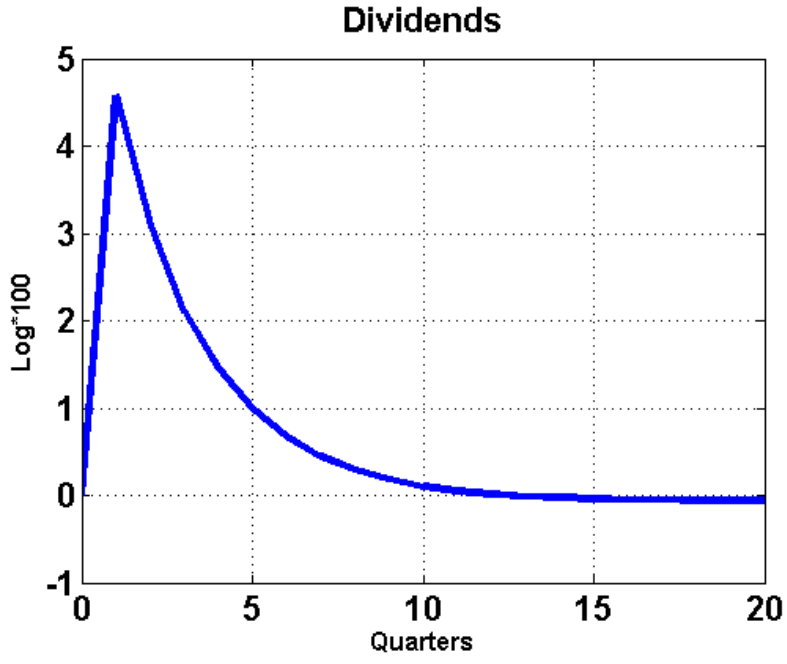
CGKS

Model

Impulse Response to MP Shock (+1%): Financial Income



CGKS



Model

Figure: Response to Contractionary Monetary Policy Shock (1%)

Result 2: Heterogeneous Welfare Effects of a MP Shock

- A contractionary (1%) monetary policy shock.
- Large differences in welfare effects across households.
  - Wealth-rich: gain from ↑ dividends.
  - Wealth-poor: lose from ↓ wage and employment.
- Divergence b/w RA and HA welfare.

%Δ in flow consumption	$\rho_u = 0$ (base)	$\rho_u = 0.25$
Social Welfare		
Representative Agent (RA)	–0.029	–0.012
Average of all HHs (HA)	–0.084	–0.037
By Wealth Holdings		
Top 5%	+0.056	+0.023
5–20%	–0.032	–0.015
20-40%	–0.061	–0.027
40-60%	–0.070	–0.032
60-80%	–0.108	–0.048
80-95%	–0.165	–0.072
Bottom 5%	–0.180	–0.079

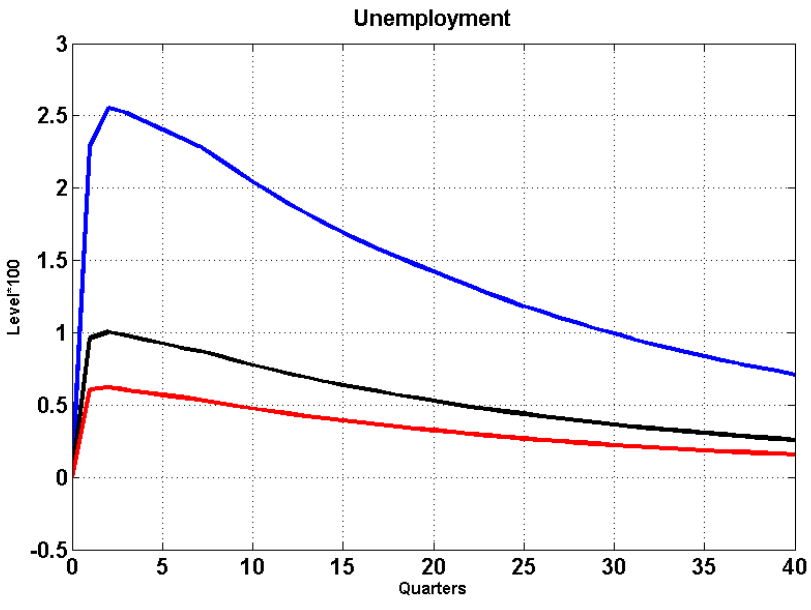
Result 3: Heterogeneous Welfare Effects of Severe Recession

- $\downarrow$ TFP shock calibrated such that output declines by 8.3%.
- Stronger response of MP compresses welfare effects.
- HA welfare gains are larger than RA welfare gains.
- Wealth-rich lose as firms are incentivised to invest/hire.

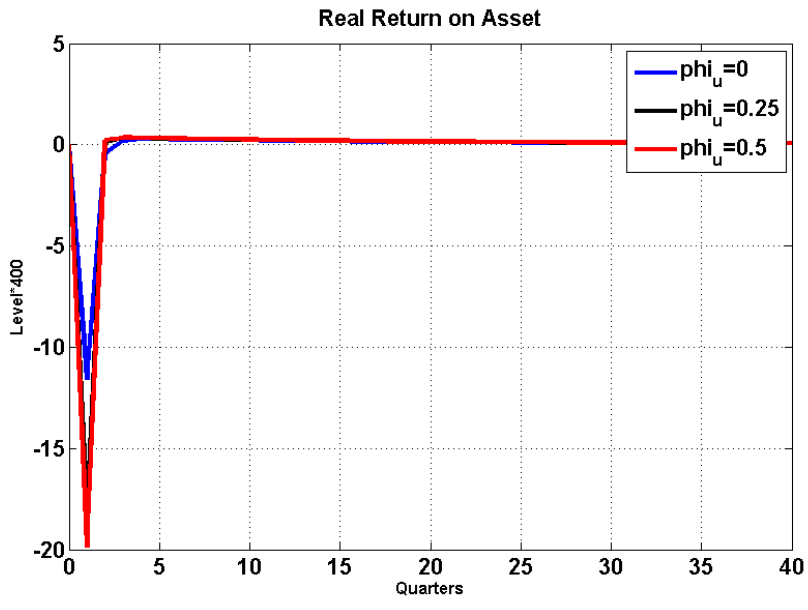
%Δ in flow consumption	$\rho_u = 0$ (base)	$\rho_u = 0.25$
Social Welfare		
Representative Agent (RA)	–2.09	–1.95
Average of all HHs (HA)	–3.04	–2.51
By Wealth Holdings		
Top 5%	–2.10	–3.24
5–20%	–2.66	–2.71
20-40%	–2.85	–2.56
40-60%	–2.94	–2.48
60-80%	–3.24	–2.36
80-95%	–3.63	–2.32
Bottom 5%	–3.73	–2.32

Result 3: Heterogeneous Welfare Effects of Severe Recession

- Wealth-poor households gain from lower unemployment rate and smaller drop in wages.
- Wealth-rich households lose from lower return on assets.



Unemployment



Real Return on Assets

Result 4: Long-Run Welfare Effects of More Responsive MP

- Welfare effects of $\rho_u = 0.0 \longrightarrow 0.25$.
- Long-run welfare gains of compressing economic fluctuations are dominated by lower output induced by lower capital stock.
- Short-run (on the transition path) gains by wealth-rich.

%Δ in flow consumption	Short-run	Long-run
Social Welfare		
Representative Agent (RA)	0.046	–0.024
Average of all HHs (HA)	0.019	–0.062
By Wealth Holdings		
Top 5%	0.161	–0.015
5–20%	0.067	–0.045
20-40%	0.038	–0.054
40-60%	0.023	–0.060
60-80%	–0.011	–0.072
80-95%	–0.043	–0.085
Bottom 5%	–0.051	–0.088

Concluding Remarks

1. We investigate heterogeneous effects of monetary policy, using an extended RBC/DSGE model featuring market incompleteness, labor market frictions, and nominal frictions.

2. Key messages:
   1. Consistent with empirical findings of CGKS, a contractionary monetary policy shock increases inequality of households' income and consumption.
   2. Through income composition channel (labor vs. financial income).
   3. Countercyclical monetary policy has redistribution effects.
   4. Long-run? Lower precautionary savings hurt everybody.

References

Albanesi, Stefania, "Inflation and inequality," *Journal of Monetary Economics*, May 2007, *54* (4), 1088–1114.

Blanchard, Olivier and Jordi Galí, "Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment," *American Economic Journal: Macroeconomics*, April 2010, *2* (2), 1–30.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, February 2005, *113* (1), 1–45.

Coibion, Olivier, Yuriy Gorodnichenko, Lorenz Kueng, and John Silvia, "Innocent Bystanders? Monetary Policy and Inequality in the U.S," NBER Working Papers 18170, National Bureau of Economic Research, Inc June 2012.

Doepke, Matthias and Martin Schneider, "Aggregate Implications of Wealth Redistribution: The Case of Inflation," *Journal of the European Economic Association*, 2006.

___ **and** ___ , "Inflation and the Redistribution of Nominal Wealth," *Journal of Political Economy*, 2006.

Erosa, Andrés and Gustavo Ventura, "On Inflation as a Regressive Consumption Tax," *Journal of Monetary Economics*, 2002, *49* (4), 761–795.

Galí, Jordi, "Monetary Policy and Unemployment," in Benjamin M. Friedman and Michael Woodford, eds., *Handbook of Monetary Economics*, Vol. 3 of *Handbook of Monetary Economics*, Elsevier, October 2010, chapter 10, pp. 487–546.

Heathcote, Jonathan, Kjetil Storesletten, and Giovanni L. Violante, "Quantitative Macroeconomics with Heterogeneous Households," *Annual Review of Economics*, 05 2009, *1* (1), 319–354.

Krusell, Per, Aysegül Sahin, and Toshihiko Mukoyama, "Labour-Market Matching with Precautionary Savings and Aggregate Fluctuations," *Review of Economic Studies*, 2010, *77* (4), 1477–1507.

Kuester, Keith, "Real Price and Wage Rigidities with Matching Frictions," *Journal of Monetary Economics*, May 2010, *57* (4), 466–477.

Meh, Césaire A., José-Víctor Ríos-Rull, and Yaz Terajima, "Aggregate and Welfare Effects of Redistribution of Wealth under Inflation and Price-level Targeting," *Journal of Monetary Economics*, September 2010, *57* (6), 637–652.

Nakajima, Makoto, "Business Cycles in the Equilibrium Model of Labor Market Search and Self-insurance," *International Economic Review*, May 2012, *53* (2), 399–432.

Romer, Christina D. and David H. Romer, "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, September 2004, *94* (4), 1055–1084.

Trigari, Antonella, "Equilibrium Unemployment, Job Flows, and Inflation Dynamics," *Journal of Money, Credit and Banking*, 02 2009, *41* (1), 1–33.

Walsh, Carl E., "Labor Market Search, Sticky Prices, and Interest Rate Policies," *Review of Economic Dynamics*, October 2005, *8* (4), 829–849.