Monetary Policy with Heterogeneous Agents

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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.

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-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: \(\rho_\Pi\), \(\rho_u\), and monetary policy shocks.

- **Government**
  - Run unemployment insurance program.
  - Adjust \(\tau\) 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 $\lambda$.

- **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

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

subject to:
\[ c + p_a(X) a' = (p_a(X) + d_a(X)) a + w(X) s (1 - \tau(X)) \] (2)

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

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

subject to:
\[ c + p_a(X) a' = (p_a(X) + d_a(X)) a + bs \]  

• \( b \): UI benefits.
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.
The central bank determines the risk-free nominal rate $R$ following a Taylor rule:

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

(5)

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

(6)

- $D$: Monetary policy shock (tighter/looser policy than usual).
- $\rho_{\Pi}$: Systematic response of policy rate, for inflation stabilization.
- $\rho_{u}$: Systematic response of policy rate, for unemployment stabilization (Blanchard and Galí (2010)).
The government runs the UI program.

\( \tau \) is adjusted to satisfy the budget constraint:

\[
0 = \tau \int_{\mathcal{M}} \mathbb{1}_{e=1} ws \; d\mu - \int_{\mathcal{M}} \mathbb{1}_{e=0} bs \; d\mu
\]  

(7)
Model: Labor Firm

\[ J_L(X, s) = (h(X) - w(X))s + \mathbb{E}Q(X, X')(1 - \lambda)J_L(X', s') \]  \hspace{1cm} (8)

\[ \kappa = \frac{M(U(X) + \lambda N(X), V(X))}{V(X)} \mathbb{E}J_L(X, s) \] \hspace{1cm} (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.
- \( \kappa \): vacancy posting cost.
- \( M(U + \lambda N, V) \): matching function.
- Ad-hoc wage function is assumed for now (\( \epsilon_w = 0.45 \)):

\[ \log(w(X)) = \log(\bar{w}) + \epsilon_w(\log(y(X)) - \log(\bar{y})) \]
Capital Firm

\[ J_K(X, k) = \max_{v, i, k'} \left\{ r(X)kv - i + \mathbb{E}Q(X, X') J_K(X', k') \right\} \]  \hspace{1cm} (10)

subject to:

\[ k' = (1 - \delta(v))k + \zeta \left( \frac{i}{k} \right) k \] \hspace{1cm} (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

\[
J_I(X, P_j, -1) = \max_{P_j, \ell_j, k_j} y_j(X, P_j) \left( \frac{P_j}{P} - \frac{\phi \Pi}{2} \left( \frac{P_j}{P_{j, -1}} - \bar{\Pi} \right)^2 \right) \\
- r(X) v(X) k_j - h(X) \ell_j + \mathbb{E} Q(X, X') J_I(X', P_j)
\]

subject to:
\[
y_j = Z_k^\theta \ell_j^{1-\theta} \\
\log(Z') = \rho_Z \log(Z) + \epsilon_Z, \text{ where } \epsilon_Z \text{ is i.i.d. } N(0, \sigma_Z^2)
\]

- Monopolistically competitive, facing quadratic price adj cost.
- \(P_j\): price of a good \(j\).
- \(P\): price of a final good (aggregate price level).
- \((k_j, \ell_j)\): capital and labor used for producing good \(j\).
- \(\phi \Pi\): parameter for quadratic price adjustment cost.
Final Good Firm

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

subject to:

\[
y = \left( \int_0^1 y_j \frac{e-1}{e} \, dj \right)^{\frac{e}{e-1}}
\]  \hspace{1cm} (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. $\tau$ satisfies the government budget constraint.
6. $R$ follows the Taylor rule.
8. All markets clear.
9. Symmetry across all intermediate goods: $P_j = P_{j'} (= P)$. 

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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

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

- 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

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

- 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

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

- Model succeeds in generating moderately volatile and procyclical productivity and wage.
- Not-so-volatile nominal interest rate and inflation.
  → 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 → Front-loading of dividends.
  → 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.

<table>
<thead>
<tr>
<th>%Δ in flow consumption</th>
<th>( \rho_u = 0 ) (base)</th>
<th>( \rho_u = 0.25 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Welfare</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Representative Agent (RA)</td>
<td>-0.029</td>
<td>-0.012</td>
</tr>
<tr>
<td>Average of all HHs (HA)</td>
<td>-0.084</td>
<td>-0.037</td>
</tr>
<tr>
<td>By Wealth Holdings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 5%</td>
<td>+0.056</td>
<td>+0.023</td>
</tr>
<tr>
<td>5–20%</td>
<td>-0.032</td>
<td>-0.015</td>
</tr>
<tr>
<td>20-40%</td>
<td>-0.061</td>
<td>-0.027</td>
</tr>
<tr>
<td>40-60%</td>
<td>-0.070</td>
<td>-0.032</td>
</tr>
<tr>
<td>60-80%</td>
<td>-0.108</td>
<td>-0.048</td>
</tr>
<tr>
<td>80-95%</td>
<td>-0.165</td>
<td>-0.072</td>
</tr>
<tr>
<td>Bottom 5%</td>
<td>-0.180</td>
<td>-0.079</td>
</tr>
</tbody>
</table>
Result 3: Heterogeneous Welfare Effects of Severe Recession

- ↓ 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.

<table>
<thead>
<tr>
<th>%Δ in flow consumption</th>
<th>ρ_u = 0 (base)</th>
<th>ρ_u = 0.25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social Welfare</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Representative Agent (RA)</td>
<td>-2.09</td>
<td>-1.95</td>
</tr>
<tr>
<td>Average of all HHs (HA)</td>
<td>-3.04</td>
<td>-2.51</td>
</tr>
<tr>
<td><strong>By Wealth Holdings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 5%</td>
<td>-2.10</td>
<td>-3.24</td>
</tr>
<tr>
<td>5–20%</td>
<td>-2.66</td>
<td>-2.71</td>
</tr>
<tr>
<td>20-40%</td>
<td>-2.85</td>
<td>-2.56</td>
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<tr>
<td>40-60%</td>
<td>-2.94</td>
<td>-2.48</td>
</tr>
<tr>
<td>60-80%</td>
<td>-3.24</td>
<td>-2.36</td>
</tr>
<tr>
<td>80-95%</td>
<td>-3.63</td>
<td>-2.32</td>
</tr>
<tr>
<td>Bottom 5%</td>
<td>-3.73</td>
<td>-2.32</td>
</tr>
</tbody>
</table>
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 Asset

Unemployment

Real Return on Assets
Result 4: Long-Run Welfare Effects of More Responsive MP

- Welfare effects of $\rho_u = 0.0 \rightarrow 0.25$.
- 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.

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


