The Transmission of Monetary Policy Operations through Redistributions and Durable Purchases

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- are typically not explicit about implementation of monetary policy (interest rate rules)
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Study alternative channel of monetary transmission. Simple DSGE model

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- non-durable and durable goods
  - key role for durables
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**Open Market Operation (OMO):** central bank sells/buys short-term bonds

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- Two interventions (OMO vs Heli) can generate a similar path for interest rates and yet have different effects
The transmission channel in our model - preview

Expansionary OMO triggers:

- an increase in prices, surprise destruction of nominal private wealth

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Sterk and Tenreyro (UCL, LSE)
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  - Ricardian Equivalence breakdown $\Rightarrow$ MP is nonneutral
Redistribution

Estimated cumulative change in net income 2007-2012 (bill.)

<table>
<thead>
<tr>
<th></th>
<th>Central government</th>
<th>Non-financial corporations</th>
<th>Banks</th>
<th>Insurance and pensions¹</th>
<th>Households²</th>
<th>Rest of world</th>
</tr>
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<tbody>
<tr>
<td><strong>United States</strong></td>
<td>900</td>
<td>310</td>
<td>150</td>
<td>-270</td>
<td>-360</td>
<td>-480</td>
</tr>
<tr>
<td><strong>United Kingdom</strong></td>
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<td><strong>Eurozone</strong></td>
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- Durables & Nominal rigidities
Key role of durables

Nominal rigidities

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  Barsky et al. (AER 2007)

Flexibility of durable goods' prices determines the effectiveness of monetary policy in sticky-price models. Sticky wages can help wage rigidity micro/macro evidence; non-random examples: Olivei-Tenreyro (AER 2007, JME 2010)

Equally, other channels worth exploring! Important implications: i) ...scal repercussions of monetary policy; ii) implementation.

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Other literature

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Doepke and Schneider (2006): revaluation effects from MP expansions cause a contraction. (Households are net debtors in their model, hence gain from expansion and work less.)
Model
Closed economy, overlapping generations.
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- 2 life cycle stages (young, old), stochastic ageing (prob. $\rho_o$) and death (prob. $\rho_x$), Gertler (1999).
- Following retirement, immediate death shock may occur.
- Population size normalized to one. Stationary population:

$$\rho_o \nu = \rho_x (1 - \nu + \rho_o \nu)$$

where $\nu$ is the fraction of young agents in the population (#newborn=#aging=#dying).
Young agents supply labor \((h_t)\), old agents are not productive
Setup

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- Agents derive utility from non-durables \((c_t)\), durables \((d_t)\) and money \((m_t)\).
Setup

- Young agents supply labor ($h_t$), old agents are not productive
- Agents derive utility from non-durables ($c_t$), durables ($d_t$) and money ($m_t$)
- Agents can also save in bonds ($b_t$)
Firms are perfectly competitive, producing durables and non-durables with the same technology. They rent labor on a competitive labor market.
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- The treasury makes a transfer $\tau_t^s$ to each household of type $s$. We denote an agent's life-cycle status by superscript $s \in \{n, y, o\}$, with $n$ denoting a newborn young agent, $y$ a pre-existing young agent, and $o$ an old agent.
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- Wealth of deceased agents equally distributed among the young. Agents derive no utility from leaving bequests.
Optimization problem old agent \((s = o)\) in real terms:

\[
V^o(a, \Gamma) = \max_{c,d,m,b} U(c, d, m) + \beta (1 - \rho_x) \mathbb{E} V^o(a', \Gamma')
\]

s.t.

\[
c + d + m + b = a + \tau^o
\]

\[
a' \equiv (1 - \delta) d + \frac{m}{1 + \pi'} + \frac{(1 + r) b}{1 + \pi'}
\]

\[
c, d, m \geq 0,
\]

where \(V^o(a, \Gamma)\) is the value function, \(a\) denotes individual wealth, \(\Gamma\) is the aggregate state and \(\pi\) is the net rate of inflation. Also, \(\beta\) is the agents’ subjective discount factor, \(\delta\) is the depreciation rate of durables and \(\mathbb{E}\) is the conditional expectations operator.
Young agents

Optimization problem young agents \((s = n, y)\)

\[
V^s(a, \Gamma) = \max_{c,d,m,b,h} U(c, d, m) - \zeta \frac{h^{1+\kappa}}{1+\kappa} + \beta (1 - \rho_o) \mathbb{E} V^y(a', \Gamma') \\
+ \beta \rho_o (1 - \rho_x) \mathbb{E} V^o(a', \Gamma')
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s.t.
\[
c + d + m + b = a + wh + \tau^{bq} + \tau^s, \\
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where \(w\) is the wage rate and \(\tau^{bq}\) is a bequest transfer. In the utility function \(\zeta > 0\) is a scaling’s parameter and \(\kappa > 0\) determines the Frisch elasticity of labor supply.
Firms operate on a linear production function:

\[ y_t = h_t. \]

Profit maximization implies that \( w_t = 1 \), that is, the real wage equals unity.
Central Bank

- The central bank controls the nominal money supply, $M_t$, by conducting open market operations. In particular, the central bank can sell or buy government bonds. We denote the stock of bonds held by the central bank as $B_{cb}^t$. 

\[B_{cb}^t = M_t \]

The central bank transfers its accounting profit - seigniorage - to the treasury. The remittance, labeled $\tau_{cb}^t$, is given by:

\[\tau_{cb}^t = r_{bt}^1 + \pi_t^0.\]
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- To analyze monetary policy shocks, we assume that $M_t$ is driven by an exogenous process subject to stochastic shocks.
Treasury

- We abstract from government consumption.
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The treasury runs a balanced budget, but starts off with an initial level of bonds $B_{t-1}^g$ (which will be negative). The treasury’s budget constraint in real terms is:

$$\frac{r_{t-1} b_{t-1}^g}{1 + \pi_t} + \tau_{t}^{cb} = \nu \rho_o \tau_{t}^n + \nu (1 - \rho_o) \tau_{t}^y + (1 - \nu) \tau_{t}^o$$

where the total amount of transfers is adjusted to balance the government’s budget.
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Net beneficiary is the government. Key how it redistributes gain.
Retired agents are assumed not to be subject to transfers/taxes, i.e. we set $\tau_t^0 = 0$. To render the model tractable, we assume that transfers to newborns equal the after tax wealth of pre-existing young agents. This is achieved by setting:

$$a_y t + \tau_y t = \tau_n t$$

where $a_y t$ is the average wealth among pre-existing young agents. What arises is a representative young agent. We preserve heterogeneity between old and young agents, as well as heterogeneity among old agents.
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Market clearing

- Market clearing constraints durables and non-durables:

\[ c_t = \nu c_{t}^{y} + (1 - \nu) c_{t}^{o} \]
\[ d_t = \nu d_{t}^{y} + (1 - \nu) d_{t}^{o} , \]

- Resource constraint, clearing conditions for money and bond market:

\[ c_t + d_t = \nu h_{t}^{y} + (1 - \delta) d_{t-1} , \]
\[ m_t = \nu m_{t}^{y} + (1 - \nu) m_{t}^{o} , \]
\[ 0 = b_{t}^{g} + b_{t}^{cb} + \nu b_{t}^{y} + (1 - \nu) b_{t}^{o} \]

- Magnitude bequest transfer:

\[ \tau_{t}^{bq} = \frac{\rho_{x} \int_{i:s=0} a_{i,t} di + \rho_{o} \rho_{x} \nu a_{t}^{y}}{\nu} \]
Equilibrium

Definition. A recursive competitive equilibrium is defined by policy rules for non-durable consumption, \( c^s(a, \Gamma) \), durable consumption, \( d^s(a, \Gamma) \), money holdings, \( m^s(a, \Gamma) \), bond holdings, \( b^s(a, \Gamma) \), labor supply, \( h^s(a, \Gamma) \), with \( s = n, y, o, cb, g \), as well as laws of motion for inflation, the nominal interest rate and the real wage, such that

- households optimize their expected life-time utility subject to their constraints and the law of motion for the aggregate state,
- the treasury and central banks follow their specified policies,
- the markets for bonds, money, goods and labor clear in every period.

The aggregate state \( \Gamma \) includes the value of the monetary policy shock, the distribution of wealth among agents, as well as the initial holdings of assets by households, the treasury and the central bank.
Remainder of presentation

1. Representative agent version; contrast to full model

2. Quantitative implementation

3. Labor market frictions
Representative agent version
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Given the transfers to newborns, the model becomes observationally equivalent to one with an infinitely-lived representative agent with subjective discount factor $\tilde{\beta} = \beta (1 - \rho_o)$. 
Monetary neutrality

- Following arguments similar to Sidrauski (1967) one can show that, provided that money and goods enter the utility function separably, monetary policy does not affect real outcomes.

- To show this, consider the representative agent’s first-order conditions for durables, labor supply, and the aggregate resource constraint:

\[
U_{c,t} = U_{d,t} + \beta (1 - \delta) E_t U_{c,t+1} \\
U_{c,t} = \zeta h_t^\kappa \\
c_t + d_t = h_t + (1 - \delta) d_{t-1}
\]

where \( U_{c,t} \) and \( U_{d,t} \) are, respectively, the agents’ marginal utilities with respect to non-durables and durables.

- Under preference separability, this is a closed dynamic system of 3 equations and 3 endogenous variables. No nominal variables enter this system.
Impact on price level

Consider the government’s present-value budget constraint:

\[ E_t \sum_{s=t}^{\infty} D_k \left( \frac{r_s}{1 + r_s} m_s - \tau^g_s \right) = \frac{m_{t-1} - (1 + r_{t-1}) (b^{g}_{t-1} + b^{cb}_{t-1})}{1 + \pi_t} \]

where \( D_s \equiv \prod_{k=t}^{s-1} \frac{1 + \pi_{k+1}}{1 + r_k} \) is the agent’s valuation of one unit of nominal wealth received in period \( s > t \), \( D_t \equiv 1 \), and \( \tau^g \equiv \nu \rho_o \tau^n_t + \nu (1 - \rho_o) \tau^y_t \) is the total transfer to the households.
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One can verify that $\frac{r_s}{1 + r_s} m_s$ and $D_s$ are constant in the representative agent model. Given that $m_{t-1}$, $b^g_{t-1}$ and $b^{cb}_{t-1}$ are predetermined, the impact of a monetary policy shock on the price level ($\pi_t$) is fully determined by its effect on the present value of government transfers,

$$\mathbb{E}_t \sum_{s=t}^{\infty} D_k \tau^g_s.$$
Wealth effects?

- From the government’s budget constraint it also follows that monetary policy shocks do not create any wealth effect in the representative agent model. Again, use that

$$\Delta E_t \sum_{s=t}^{\infty} D_k \tau_s^g = -\Delta \frac{m_{t-1} - (1 + r_{t-1}) (b_{t-1}^g + b_{t-1}^{cb})}{1 + \pi_t}$$

(1)

and note that $$\frac{m_{t-1} - (1 + r_{t-1}) (b_{t-1}^g + b_{t-1}^{cb})}{1 + \pi_t}$$ represents the net nominal claim of the representative household on the government.

- The surprise revaluation of nominal wealth of the representative households exactly offsets the change in the present value of government transfers.

- Hence monetary policy shocks do not create wealth effects in the representative agent model. With heterogeneous agents, the revaluation of nominal wealth and the change in transfers do not affect agents equally (Weil (1991)).
Quantitative implementation
Computation

- Models with wealth heterogeneity and aggregate fluctuations typically difficult to solve, because wealth distribution is part of the economic state (Krusell and Smith (1998)).
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- Despite the presence of heterogeneity, our model can be solved using standard methods (first-order perturbation), under the following preferences:

\[
U(c_{i,t}, d_{i,t}, m_{i,t}) = \frac{x_{i,t}^{1-\sigma} - 1}{1 - \sigma},
\]

\[
x_{i,t} \equiv \left[ c_{i,t}^{\frac{\epsilon-1}{\epsilon}} + \eta d_{i,t}^{\frac{\epsilon-1}{\epsilon}} + \mu m_{i,t}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}},
\]

\[
\sigma, \epsilon, \eta, \mu > 0.
\]
Computation

Idea:

1. Write decision rule of as $x_{i,t} = \gamma_{x,i,t}a_{i,t}$ with $x = c, d, m, b$
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3. Compute aggregate variables of the old as: $x^o_t = \gamma_{x,t} a^o_t$
   - where $a^o_t = (1 - \rho_x) \left( (1 - \delta) d^o_{t-1} + \frac{m^o_{t-1} + (1+r_{t-1}) b^o_{t-1}}{1+\pi_t} \right) + \rho_o \left( (1 - \rho_x) \frac{\nu}{1-\nu} \left[ (1 - \delta) d^y_{t-1} + \frac{m^y_{t-1} + (1+r_{t-1}) b^y_{t-1}}{1+\pi_t} \right] \right)$.
Shock process

Money growth rule:

\[ \frac{M_t}{M_{t-1}} = 1 + z_t \]

where \( z_t \) is an exogenous shock process following:

\[ z_t = \xi (m_{t-1} - m_0) + \epsilon_t, \; \xi \in [0, 1], \]

where \( \epsilon_t \) is an i.i.d. shock innovation. (Implicit inflation target is zero.)
**Parameter values (quarterly model)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.9732</td>
<td>target 4% s.s. annual interest rate</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.31</td>
<td>target 20% s.s. spending on durables (NIPA)</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.0068</td>
<td>target 1.8 s.s. M2 velocity ($\frac{y}{m}$) (FRB/NIPA)</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>1</td>
<td>convention macro literature</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>1</td>
<td>convention macro literature</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>1</td>
<td>convention macro literature</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.5795</td>
<td>normalize aggregate quarterly output to one</td>
</tr>
<tr>
<td>$\rho_o$</td>
<td>0.0063</td>
<td>average duration working life 40 years</td>
</tr>
<tr>
<td>$\rho_x$</td>
<td>0.0125</td>
<td>average duration retirement 20 years</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.04</td>
<td>Baxter (1996)</td>
</tr>
<tr>
<td>$b_g$</td>
<td>-2.4</td>
<td>government debt 60% of annual output</td>
</tr>
<tr>
<td>$b_{cb}$</td>
<td>0</td>
<td>no initial central bank debt</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.15</td>
<td>half life response nominal interest rate 2.5 years</td>
</tr>
<tr>
<td>$j$</td>
<td>4</td>
<td>one year delay</td>
</tr>
</tbody>
</table>
Monetary expansion

Sterk and Tenreyro (UCL, LSE)
Young versus old
Redistributional effect consistent with Doepke and Schneider (2006) and Coibon et al. (2012).
The transmission channel with heterogeneous agents

Following a monetary expansion negative wealth effect due to downward revaluation in nominal wealth

- redistribution towards government (future generations)
- old lose more than young
- larger drop in expected life-time income upon retirement (impaired life-cycle smoothing)
- stronger savings motive $\Rightarrow$ lower real interest rate $\Rightarrow$ more durable purchases

- Price response
The transmission channel with heterogeneous agents

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  - need prices to respond before bonds reach maturity
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Price response

- need prices to respond before bonds reach maturity
- latest empirical results: prices respond on impact (Gertler and Karadi, 2014)
The transmission channel with heterogeneous agents

- The effects of savings behavior can be seen from young agents’ first-order conditions for durables and bonds:

\[
U_{c,t}^y = U_{d,t}^y + \beta (1 - \rho_o) (1 - \delta) \mathbb{E}_t U_{c,t+1}^y + \beta \rho_o (1 - \rho_x) \mathbb{E}_t \frac{U_{c,t+1}^{yo}}{1 + \pi_{t+1}}
\]

\[
U_{c,t}^y = \beta (1 - \rho_o) \mathbb{E}_t \frac{(1 + r_t) U_{c,t+1}^y}{1 + \pi_{t+1}} + \beta \rho_o (1 - \rho_x) \mathbb{E}_t \frac{(1 + r_t) U_{c,t+1}^{yo}}{1 + \pi_{t+1}}
\]

where superscript \textit{yo} denotes a newly retired agent.

- Redistributinal effect increases \( U_{c,t+1}^{yo} \Rightarrow \) stronger savings motive \Rightarrow more durable purchases, lower real interest rate
The transmission channel with heterogeneous agents

- The effect on output can be seen from the young agents' labor supply condition:

\[ U_{c,t}^y = \zeta h_t^\kappa \]
The transmission channel with heterogeneous agents

- The effect on output can be seen from the young agents’ labor supply condition:

  \[ U^y_{c,t} = \zeta h^\kappa_t \]

- Intuition:
The transmission channel with heterogeneous agents

- The effect on output can be seen from the young agents’ labor supply condition:
  \[ U_{c,t}^y = \zeta h_t^\kappa \]

- Intuition:
  - decline in nominal wealth compensated for by increased durable purchases, at the expense of current non-durable consumption
The transmission channel with heterogeneous agents

- The effect on output can be seen from the young agents’ labor supply condition:

\[ U_{c,t}^y = \zeta h_t^\kappa \]

- Intuition:
  - decline in nominal wealth compensated for by increased durable purchases, at the expense of current non-durable consumption
  - leisure is a normal good here, so young agents increase labor supply
Monetary expansion

OMO vs helicopter drop

Sterk and Tenreyro (UCL, LSE)
Monetary expansion
role of risk aversion

Sterk and Tenreyro (UCL, LSE)
New Keynesian literature

- Sticky price models with durables have counterfactual properties
  Barsky et al. (2007)
    - durable prices arguably relatively flexible
    - in that case, relative price of durable increases after monetary expansion
    - this leads to a *decline* in durable purchases

- Sticky-wage models argued to be more successful, but large adjustment costs needed to avoid very short-lived spike in durables (Carlstrom and Fuerst (2006))
Labor market frictions
Response of output

- In our benchmark model, the increase in output following an expansionary OMO is driven by a labor supply effect.
- It turns out that with search and matching frictions in the labor market, output also increases but due to a labor demand effect.
Unemployment

- Young agents can be unemployed or matched with a firm. A worker-firm pair produces one unit of output.
- Separation occurs 1) with retirement; or 2) with probability $\rho_s$.
- Overall separation probability $\tilde{\rho}_s = \rho_o + (1 - \rho_o)\rho_s$
- Newborns enter the economy as unemployed
The number of job searchers in the economy is

\[ s_t = \rho_o \nu + (1 - \rho_o) \rho_s n_{t-1}. \]

Income insurance among workers. No heterogeneity among young agents.

Matching occurs at the beginning of the period, after aggregate and individual shocks have realized, but before production takes place.

The evolution of the employment rate among young agents, denoted \( n_t \), is given by:

\[ n_t = (1 - \tilde{\rho}_s) n_{t-1} + g_t, \]

where \( g_t \) denotes the number of new hires in period \( t \).
The asset value of a firm matched with a worker is given by:

\[ V_t = 1 - w_t + (1 - \tilde{\rho}_s) \Lambda_{t,t+1} V_{t+1}, \]

where \( \Lambda_{t,t+1} \) is the stochastic discount factor of the owner of the firm. For simplicity we assume that only young agents are able to run firms.

Unmatched firms search after paying a cost \( \chi \). Free entry of firms, which implies that

\[ \chi = \lambda_t v_t, \]

where \( \lambda_t \equiv \frac{g_t}{v_t} \) is the probability of finding a worker, \( v_t \) is the total number of vacancies.

Number of new matches follows from an aggregate matching function:

\[ g_t = s_t^\alpha v_t^{1-\alpha}. \]
Wage setting + parameter values

- We assume the *real wage* is fixed, i.e. $w_t = \bar{w}$. (we check $\bar{w}$ is in the bargaining set)
- We use $\bar{w}$ to target a steady-state unemployment rate of 5%.
- Matching function elasticity, $\alpha$ is set to 0.5. Separation rate $\rho_s$ chosen to imply $\tilde{\rho}_s = 0.1$, overall separation rate of ten percent per quarter.
- Vacancy cost, $\chi$, calibrated to imply steady-state cost of hiring a worker of 5% of quarterly output.
Monetary expansion

Sterk and Tenreyro (UCL, LSE)
Summary of Extensions

- Labour market frictions: search and matching frictions
  - employment response due to firms’ demand, rather than increased labour supply

- Search and matching frictions plus Big OLG structure (deterministic aging, 40 years)

- Risk aversion

- Banks
Take home messages

- Monetary non-neutrality even without nominal rigidities.
  - Anything that breaks RE; allowing for retirement

- Transmission through wealth/redistributional effects
  - Can help NK model in getting the right response of durables when their prices are more flexible

- Operating procedure (OMO, helicopter drops) important
  - Similar interest rate changes can have different aggregate effects

- Monetary policy is fiscal policy