State Dependent Effects of Monetary Policy: The Refinancing Channel

Martin Eichenbaum, Sergio Rebelo, and Arlene Wong

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Document state dependent effects of monetary policy

- **Context:**
  - In the U.S., most mortgages have fixed rates.
  - Refi decision depends on potential interest savings vs. costs.

- **Empirically:**
  - Refinancing and housing permit response to a given interest rate cut is larger when potential savings are higher.

- Develop a quantitative model that capture empirical findings:
  - Study how paths of interest rates affects the distribution of rate gaps and the effect of a given rate cut.
  - Study decline in refi costs, motivated by Fintech lenders.
Related Literature

- **Mortgage refinancing literature:**

- **State-dependent effects of monetary policy related to the mortgage market:**

- **Liquid and illiquid asset models:**
Data

- Core Logic Loan-Level Market Analytics database:
  - > 60% market coverage of first mortgages back to 1995.
  - Loan-level panel data with information on amount, interest rate, LTV and purpose of loan (i.e. refi, purchase). Borrower characteristics (e.g. FICO, ZIP code).
  - Quarterly frequency. Sample of 12 million observations, and 1.8 million loans.
  - Focus on the pre-2008 period.
- Freddie Mac Loan-Level database from 1999 onwards.
Data

- We consider two measures of potential savings from refinancing:
  1. Simple interest rate gap relative to current mortgage rate;
  2. Present value of potential savings;

- In general, not sufficient statistics. But highly correlated with refinancing, and direct moments computed in model and data.

- Contribution of this paper: quantify the state-dependent effects of monetary policy related to the distribution of potential savings.
Interest rate gap

For each individual $i$ at time $t$

$$r_{it}^{gap} = r_{it}^{old} - r (Z_{it})^{new}$$

- $r_{it}^{old}$ is consumer $i$'s existing mortgage rate.
- $r (Z_{it})^{new}$ is the new rate for a consumer with characteristics $Z$:
  - FICO score bins: below 600, 600-620, ..., 760-780, >780.
  - Region of residence.

Also considered present value of potential savings.
Distribution of interest rate gaps in 1997 and 2000

State Dependent Effects of Monetary Policy: The Refinancing Channel
Refinancing Response to Monetary Policy Shocks

For county $c$ in quarter $t$, we estimate

$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R^M_t + \beta_2 \Delta R^M_t \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.$$  

where $\psi_{c,t-1}$ is a moment of distribution (e.g. average rate gap).

- Potential challenges to identification: e.g. shocks and unobservable variables affecting both refinancing and mortgage rates.

- Two approaches
  - Include time fixed effects
  - IV with high frequency data on Federal Funds futures and Treasury yields, and its interactions with $\psi_{c,t-1}$.
Refinancing Response to Monetary Policy Shocks

\[ \Delta \text{Mortgage rate}_{t,t+k} = \alpha_0 + \alpha_1 \epsilon_t + \eta_t \]

<table>
<thead>
<tr>
<th>Change in mortgage rate</th>
<th>30-year (I)</th>
<th>15-year (II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock based on Fed Funds Futures</td>
<td>0.599**</td>
<td>0.585**</td>
</tr>
<tr>
<td></td>
<td>(0.281)</td>
<td>(0.249)</td>
</tr>
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</table>

- Mortgage rates respond to identified shocks.
- F-statistic on first stage estimates exceed 20.
State dependent effects of monetary policy

For county c in quarter t, we estimate

\[ \rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}. \]

IV with Fed funds futures shocks, and its interaction with \( \psi \).

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<tr>
<td>( \Delta R(t) \times \text{Average rate gap} )</td>
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County Fixed Effects | Yes | Yes | Yes
SPF Controls | Yes | Yes
Additional county controls | Yes
State dependent effects of monetary policy

For county $c$ in quarter $t$, we estimate

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Average refi rate is 8.5%. Suppose mortgage rates fell by 25bp:
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For county \( c \) in quarter \( t \), we estimate

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\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R^M_t + \beta_2 \Delta R^M_t \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.
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Average refi rate is 8.5%. Suppose mortgage rates fell by 25bp:

- If rate gap is -14bp (mean), refinancing increases by 0.13ppts \( (\beta_1 \times 0.25 + \beta_2 \times 0.25 \times -0.14) \).
State dependent effects of monetary policy

For county $c$ in quarter $t$, we estimate

$$
\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R^M_t + \beta_2 \Delta R^M_t \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.
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Average refi rate is 8.5%. Suppose mortgage rates fell by 25bp:

- If rate gap is -14bp (mean), refinancing increases by 0.13ppts.

- If rate gap is 56bps (mean+1sd), refinancing increases by 6.93ppts ($\beta_1 \times 0.25 + \beta_2 \times 0.25 \times 0.56$).
State dependent effects of monetary policy

For county $c$ in quarter $t$, we estimate

$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.$$

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- If rate gap is -14bp (mean), refinancing increases by 0.13ppts.
- If rate gap is 56bps (mean+1sd), refinancing increases by 6.93ppts.
- Marginal impact of a 1sd increase in rate gap is 6.8 ppts.
State dependent effects of monetary policy

For county $c$ in quarter $t$, we estimate

$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}. \quad \text{IV with Fed funds futures shocks, and its interaction with } \psi.$$ 

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- Results are robust to including controls, such as SPF expectations and county controls (lender competitiveness, home equity, house price accumulation, unemployment, manufacturing share, average age, share college edu, share ARM, etc).
Change in balance, given cash-out refinancing

For county \( c \) in quarter \( t \), we estimate

\[
\Delta \log \text{balance}_{c,t+4} = \beta_0 + \beta_1 \Delta R^M_t + \beta_2 \Delta R^M_t \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.
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Suppose mortgage rates fell by 25bp:

- If rate gap is -14bp (mean), balance increases by 3.3 ppts.
- If rate gap is 56bps (mean+1sd), balance increases by 6.4 ppts.
- Marginal impact of a 1sd increase in rate gap is 3.1 ppts. This equal $3,700 equity extraction, on a mortgage of $123K.
Real outcomes

- Permits required for new privately-owned residential buildings.
  - It is a leading economic indicator, the only component of the Conference Board leading indicator index available at the county-level.
  - Monthly county data from Census Building Permits Survey, aggregated to quarterly frequency, from 2000.

- Auto purchases (Berger et al, 2018)

- Evidence of state-dependent effects of monetary policy, related to the distribution of existing rate gaps.
State dependent effects: other moments

- Median savings.
- Average positive savings.
- Fraction of loans with positive savings.
- Fraction of loans above the Agarwal, Driscoll and Laibson (2013) threshold.
Household model: set-up

1. Life-cycle

2. Idiosyncratic income risk and aggregate shocks

3. Assets: - liquid one-period asset
   - illiquid housing and fixed rate mortgage

4. Fixed cost of adjusting the mortgage and housing
   - $F$: calibrated to match average refi rate.

5. Borrowing constraints: short-term constraint; mortgage LTV constraint
Value function

\[ V(z) = \max \{ V(z)^{\text{own \& adjust}}, V(z)^{\text{own \& noadjust}}, V(z)^{\text{rent}} \} \]

where

\[ V(z)^k = \max u(c, h^k) + \beta E[V(z')] \quad \text{s.t.} \]

- Own home and adjust loan:
  - balance and mortgage rate can adjust
  - housing owned can adjust
  - pay cost \( F \)

- Own home and do not adjust loan

- Rent
State variables

\[ z = \{a, \eta, K, S\} \]

- \( a, \eta, K \): age, idiosyncratic labor income, and asset holdings.
- \( K \): short-term assets, housing stock, mortgage balance, and existing mortgage rate.
- \( S \): aggregate state \([\log Y, \log(p), \log(r)]\)
State variables

- **Aggregate states**: \( S = [\log Y, \log(p), \log(r)] \)

\[ S_t = A_0(Z_{t-1}) + A_1(Z_{t-1}) \cdot S_{t-1} + u_t \]

where \( Z_{t-1} \) includes \( S_{t-1} \) and the distribution of individual states across households.

- **Approximate the process with**

\[ S_t = a_0 + a_1 S_{t-1} + a_2 \psi_{t-1} + a_3 S_{t-1} \cdot \psi_{t-1} + u_t \]

\[ \psi_{t-1} = b_0 + b_1 S_{t-1} + b_2 \psi_{t-1} + b_3 S_{t-1} \cdot \psi_{t-1} + \nu_t \]

where \( \psi_t \) denotes the log of average savings.
Mortgage rate and rental rate

- Hard for traditional asset pricing models to account for empirical properties of mortgage interest rates, rental rates and housing prices.

- We assume interest rate of mortgage is

\[ r_t^m = f^m(S_t). \]

- Rental rate is given by:

\[ \log(p_t^r) = f^p(S_t). \]
Model calibration

Exogenously set parameters:

- Model is annual
- Intertemporal elasticity $\sigma = 2$
- Housing depreciation rate $\delta = 3\%$
- Collateral constraint $\phi = 0.2$
- Income process with $\rho = 0.91, \sigma_y = 0.21$ (Hurst et al, 2014)
- Income exposure to aggregate shocks: $\phi_a$ from CPS

Calibrated parameters:

- Utility parameter $\alpha = 0.88$ and discount rate $\beta = 0.962$ chosen to match $W/Y = 2.3$ and homeownership rate $= 66\%$.
- $F =$ approximately $2.1K$ (2\% of median house price) chosen to match average quarterly fraction of new loans of 4.5\%. 

State Dependent Effects of Monetary Policy: The Refinancing Channel
Model fit: life-cycle moments

- Home Ownership Rate: Percent of households
  - 25-35: 40
  - 35-45: 60
  - 45-55: 80
  - 55-65: 100
  - 65+: 80

- Non-durable Consumption: Relative to the 25-35 group
  - 25-35: 0
  - 35-45: 0.2
  - 45-55: 0.15
  - 55-65: 0.1
  - 65+: 0.05

- Household Debt Ratios: Relative to the 25-35 group
  - 25-35: 1.2
  - 35-45: 1.0
  - 45-55: 0.8
  - 55-65: 0.6
  - 65+: 0.4

- Household Net Wealth: Relative to the old
  - 25-35: 0.4
  - 35-45: 0.6
  - 45-55: 0.8
  - 55-65: 1.0
  - 65+: 1.2

State Dependent Effects of Monetary Policy: The Refinancing Channel
Model fit: refinancing and rate gap correlation
Model fit: state dependent effects of monetary policy

- Start the simulation in 1994, where agents have the distribution of assets, liabilities and mortgage rates that we observe in the data.

- Feed in actual prices and real variables from 1995 to 2007.

- Simulate idiosyncratic income shocks.

- Compute household’s decisions.
Model fit: state dependent effects of monetary policy

- Simulate the model and compute refinancing regression.
- Dependent variable: percentage of mortgages that is refinanced.

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Larger refi response for given rate cut, when rate gap is higher.
Consumption response and constrained households

- Consumption rises by 1% over the year after a 25bp rate cut.
- Driven by constrained households (40% of all households).
- Of those who refinance, 80% engage in cash-out refinancing
  - in line with evidence from Chen, Michaux, and Roussanov (2013).
- If $R_t$ fell by 25bps, balances rise by about 4% for cash-out refinance
  - in line with evidence from Bhutta and Keys (2016)
Experiments

1. Study the effect of a 1 ppt monetary shock, that is preceded by:
   - Sequence of monetary shocks that increases rates;
   - Sequence with no monetary shocks so that rates are flat;
   - Sequence of monetary shocks that decreases rates.

2. Study the effect of lower transaction costs on the state-dependent effects of monetary policy.
Experiment I: Asymmetric paths

Alternative rate paths prior to rate cut

State Dependent Effects of Monetary Policy: The Refinancing Channel
Experiment I: Asymmetric paths

<table>
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<tr>
<th>Rate path prior to a 1 ppt cut</th>
<th>Average rate gap before cut</th>
<th>Fraction with positive rate gap, after rate cut</th>
<th>Effect on refinancing</th>
<th>Change in consumption</th>
<th>Fraction ST constrained</th>
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<tbody>
<tr>
<td><strong>Panel A: Asymmetric effects of Flat vs Rising</strong></td>
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<tr>
<td>(i) Flat at about 3.5%</td>
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<td>100%</td>
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<td>2.4%</td>
<td>0.47</td>
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<td>(ii) Rising from 3.5% to 6.5% over 4 periods</td>
<td>-0.81%</td>
<td>22%</td>
<td>5%</td>
<td>0.1%</td>
<td>0.60</td>
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<tr>
<td>Difference (i)-(ii)</td>
<td>0.81%</td>
<td>78%</td>
<td>20%</td>
<td>2.3%</td>
<td>-0.13</td>
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<td><strong>Panel B: Asymmetric effects of Flat vs Falling</strong></td>
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<td>2%</td>
<td>0.9%</td>
<td>0.15</td>
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- Rate rises: negative rate gaps, as households locked in lower rates.
- Rate declines: positive rate gaps and smaller share of constrained.
## Experiment II: Lower transaction costs

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### Effect on refinancing:

- Overall effect of a 25 bp fall in rates: 2.76% (2.1K) / 4.02% (1K)
- $\beta_1 \Delta R_t$: 0.95% (2.1K) / 2.90% (1K)
- $\beta_2 \Delta R_t \times \text{mean}(\psi_t)$: 1.81% (2.1K) / 1.12% (1K)

### Effect on consumption:

- Overall effect of a 25 bp fall in rates: 1.03% (2.1K) / 1.30% (1K)
- $\beta_1 \Delta R_t$: 0.60% (2.1K) / 0.88% (1K)
- $\beta_2 \Delta R_t \times \text{mean}(\psi_t)$: 0.42% (2.1K) / 0.36% (1K)

Lower transaction costs lead to:

- Higher overall response to lower rates, given an initial rate gap
- State-dependent effects change (average rate gap is lower).
**Experiment II: Lower transaction costs**

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- Overall effect of a 25 bp fall in rates: 2.76% 4.02%
- $\beta_1 \Delta R_t$: 0.95% 2.90%
- $\beta_2 \Delta R_t$ times mean($\phi_t$): 1.81% 1.12%

**Effect on consumption:**

- Overall effect of a 25 bp fall in rates: 1.03% 1.30%
- $\beta_1 \Delta R_t$: 0.60% 0.88%
- $\beta_2 \Delta R_t$ times mean($\phi_t$): 0.42% 0.36%

Lower transaction costs lead to:

- Higher overall response to lower rates, given an initial rate gap
- Less state-dependent effects (average rate gap is lower).
## Experiment II: Lower transaction costs

<table>
<thead>
<tr>
<th>Fixed cost</th>
<th>$2.1K</th>
<th>$1K</th>
</tr>
</thead>
</table>

### Effect on refinancing:
- **Overall effect of a 25 bp fall in rates**
  - $2.1K: 2.76%
  - $1K: 4.02%
- $\beta_1 \Delta R_t$
  - $2.1K$: 0.95%
  - $1K$: 2.90%
- $\beta_2 \Delta R_t \text{ times mean}(\varphi_t)$
  - $2.1K$: 1.81%
  - $1K$: 1.12%

### Effect on consumption:
- **Overall effect of a 25 bp fall in rates**
  - $2.1K$: 1.03%
  - $1K$: 1.30%
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  - $2.1K$: 0.60%
  - $1K$: 0.88%
- $\beta_2 \Delta R_t \text{ times mean}(\varphi_t)$
  - $2.1K$: 0.42%
  - $1K$: 0.36%

## Lower transaction costs lead to:
- **Higher overall response to lower rates, given an initial rate gap**
- **Less state-dependent effects (average rate gap is lower).**
Experiment II: Lower transaction costs

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Lower transaction costs lead to:
- Higher overall response to lower rates, given an initial rate gap
- Less state-dependent effects (average rate gap is lower).
Conclusion

- Refinancing and consumption respond more to a given interest rate cut when potential savings are greater.

- Historical paths of interest rates affect future efficacy of monetary policy, through the refinancing channel.

- Lower transaction costs lead to more refinancing and smaller state dependent effects of monetary policy.
Spare slides
State dependency: Average savings

For county $c$ in quarter $t$, we estimate

$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.$$ 

<table>
<thead>
<tr>
<th>OLS</th>
<th>IV using</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortgage rate</td>
<td>Futures Treasury</td>
</tr>
<tr>
<td>(I)</td>
<td>(II) (III)</td>
</tr>
<tr>
<td>0.074***</td>
<td>0.130***</td>
</tr>
<tr>
<td>(0.003)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Futures Δ2yr Treasury</td>
<td>Futures Δ2yr Treasury</td>
</tr>
<tr>
<td>(IV)</td>
<td>(V) (VI)</td>
</tr>
<tr>
<td>0.013***</td>
<td>0.056***</td>
</tr>
<tr>
<td>(0.002)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>ΔR(t) x Average savings</td>
<td>Futures Δ2yr Treasury</td>
</tr>
<tr>
<td>(VII)</td>
<td></td>
</tr>
<tr>
<td>0.013***</td>
<td>0.144**</td>
</tr>
<tr>
<td>(0.002)</td>
<td>(0.009)</td>
</tr>
</tbody>
</table>

County Fixed Effects: Yes, Yes, Yes, Yes, Yes, Yes, Yes
SPF Controls: No, No, No, Yes, Yes, Yes, Yes
Additional county controls: No, No, No, No, Yes, Yes

Average refi rate is 8.5%. Suppose mortgage rates fell by 25bp:

- If savings is -$305 (mean), refinancing increases by 2.22ppts.
- If savings is $4,422 (mean+1sd), refinancing increases by 7.88ppts.
- Marginal impact of a 1sd increase in savings is 5.66ppts.
State dependency: Gap above ADL threshold

For county $c$ in quarter $t$, we estimate

$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R^M_t + \beta_2 \Delta R^M_t \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}. $$

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>OLS</th>
<th>IV using</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortgage rate</td>
<td>Futures</td>
<td>Δ2yr Treasury</td>
</tr>
<tr>
<td>ΔR(t)</td>
<td>(I)</td>
<td>(II)</td>
<td>(III)</td>
</tr>
<tr>
<td></td>
<td>0.076***</td>
<td>0.330***</td>
<td>0.331</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.070)</td>
<td>(0.173)</td>
</tr>
<tr>
<td>ΔR(t) x (i-i0-ADL)</td>
<td>0.021</td>
<td>0.209**</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.073)</td>
<td>(0.119)</td>
</tr>
<tr>
<td>ΔR(t) x (i-i0-ADL)</td>
<td></td>
<td>0.331***</td>
<td>0.109</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.062)</td>
<td>(0.070)</td>
</tr>
<tr>
<td>ε(t)</td>
<td></td>
<td>0.121***</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.036)</td>
<td>(0.054)</td>
</tr>
<tr>
<td>SPF Controls</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
More people refinance when savings are higher

Focus on the pre-2008 period.
# State Dependency: Additional Controls

<table>
<thead>
<tr>
<th></th>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta R(t) \times \text{Average savings}(t-1) )</td>
<td>0.047***</td>
<td>0.044***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta R(t) \times \text{Average rate gap}(t-1) )</td>
<td></td>
<td>0.472***</td>
<td>0.408***</td>
<td></td>
</tr>
<tr>
<td>( \Delta R(t) \times \text{Home equity}(t-1) )</td>
<td>0.204</td>
<td></td>
<td>0.180</td>
<td></td>
</tr>
<tr>
<td>( \Delta R(t) \times \text{Unemployment rate}(t-1) )</td>
<td>-0.015</td>
<td>-0.026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta R(t) \times \text{Median age}(t-1) )</td>
<td>-0.003*</td>
<td></td>
<td>-0.003*</td>
<td></td>
</tr>
<tr>
<td>( \Delta R(t) \times \text{Manufacturing share}(t-1) )</td>
<td>0.006*</td>
<td></td>
<td>0.008*</td>
<td></td>
</tr>
<tr>
<td>( \Delta R(t) \times \text{Share college educated}(t-1) )</td>
<td>-0.030</td>
<td></td>
<td>0.028</td>
<td></td>
</tr>
</tbody>
</table>

|                           |           |            |            |            |
| County Fixed Effects      | Yes       | Yes        | Yes        | Yes        |
| County interaction controls| Yes       | Yes        | Yes        | Yes        |
## County characteristics and average rate gaps

<table>
<thead>
<tr>
<th>Time FE</th>
<th>Yes</th>
<th>Yes</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>County FE</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.738</td>
<td>0.543</td>
<td>0.187</td>
<td>0.0546</td>
<td>0.0257</td>
<td>0.0119</td>
<td>0.0042</td>
<td>0.0004</td>
<td>0.0001</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variables:</td>
<td>(I)</td>
<td>(II)</td>
<td>(III)</td>
<td>(IV)</td>
<td>(V)</td>
<td>(VI)</td>
<td>(VII)</td>
<td>(VIII)</td>
<td>(XIV)</td>
<td>(X)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unemployment rate $0.0818^{***}$

(0.010)

Per capita income $-0.3566^{***}$

(0.020)

Share college educated $-0.5863^{***}$

(0.050)

Home equity accumulation $-0.5117^{***}$

(0.060)

Median age $0.0909^{*}$

(0.040)

Manufacturing share $0.0003$

(0.000)

Share male $0.2296$

(0.410)

- Most variation due to aggregate trends and persistent heterogeneity.
- Rate gap rises with unemployment and age; declines with education and home equity. But persistent unobserved heterogeneity remains.
- Consistent with household evidence – e.g. Bhutta and Keys (2016), Anderson, Campbell, Nielsen and Ramadorai (2015).
Identification of monetary policy shocks
Mean real mortgage rate and cross-sectional standard deviation

Dashed lines denote 2-std deviations about the mean.
Refinancing relationship breaks down post 2007

Average savings ($000)

-10 -5 0 5 10

1995q1 2000q1 2005q1 2010q1 2015q1

Average savings
% loans refi

State Dependent Effects of Monetary Policy: The Refinancing Channel
### First stage estimates: Average rate gap

<table>
<thead>
<tr>
<th>First stage y-variable:</th>
<th>$\Delta R(t)$</th>
<th>$\Delta R(t) \times \text{average positive rate gap}$</th>
<th>$\Delta R(t)$</th>
<th>$\Delta R(t) \times \text{average positive rate gap}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regressed on shock type:</td>
<td>Futures shock (II)</td>
<td>Futures shock (II)</td>
<td>Δ 2-yr Treasury Rate (III)</td>
<td>Δ 2-yr Treasury Rate (IV)</td>
</tr>
<tr>
<td>$\varepsilon(t)$</td>
<td>1.466***</td>
<td>0.385***</td>
<td>0.985***</td>
<td>0.261***</td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.033)</td>
<td>(0.012)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>$\varepsilon(t) \times \text{Average rate gap}$</td>
<td>0.048</td>
<td>0.487***</td>
<td>-0.107***</td>
<td>0.104***</td>
</tr>
<tr>
<td></td>
<td>(0.256)</td>
<td>(0.095)</td>
<td>(0.017)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.734</td>
<td>0.557</td>
<td>0.287</td>
<td>0.170</td>
</tr>
</tbody>
</table>
**First stage estimates: Average potential savings**

<table>
<thead>
<tr>
<th>First stage y-variable:</th>
<th>$\Delta R(t)$</th>
<th>$\Delta R(t) \times \text{Average savings}$</th>
<th>$\Delta R(t)$</th>
<th>$\Delta R(t) \times \text{Average savings}$</th>
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<tr>
<td>Regressed on shock type:</td>
<td>Futures shock (II)</td>
<td>Futures shock (II)</td>
<td>$\Delta$ 2-yr Treasury Rate (III)</td>
<td>$\Delta$ 2-yr Treasury Rate (IV)</td>
</tr>
<tr>
<td>$\varepsilon(t)$</td>
<td>1.583***</td>
<td>1.738***</td>
<td>0.951***</td>
<td>-1.355***</td>
</tr>
<tr>
<td></td>
<td>(0.113)</td>
<td>(0.130)</td>
<td>(0.011)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>$\varepsilon(t) \times \text{Average savings}$</td>
<td>-0.059</td>
<td>0.791***</td>
<td>-0.024***</td>
<td>0.162***</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.159)</td>
<td>(0.003)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.293</td>
<td>0.156</td>
<td>0.288</td>
<td>0.177</td>
</tr>
</tbody>
</table>
Real outcomes: building permits and average savings

For county $c$ in quarter $t$, we estimate

$$\Delta \log \text{Permits}_{t,t+4} = \beta_0 + \beta_1 \Delta R^M_t + \beta_2 \Delta R^M_t \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.$$ 

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Mortgage rate</td>
<td>Futures</td>
</tr>
<tr>
<td>(I)</td>
<td>(II)</td>
</tr>
<tr>
<td>ΔR(t)</td>
<td>0.209***</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
</tr>
<tr>
<td>ΔR(t) x Average savings</td>
<td>0.012**</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>County Fixed Effects</td>
<td>Yes</td>
</tr>
<tr>
<td>SPF Controls</td>
<td>No</td>
</tr>
<tr>
<td>Additional county controls</td>
<td>No</td>
</tr>
</tbody>
</table>

Mean permit growth -1.2%, std 46%. If mortgage rates fell 25bps:

- If savings is -$305 (mean), permits growth rate 5.54ppts.
- If savings is $4,422 (mean+1sd), permits growth rate 22.05ppts.
- Marginal impact of a 1sd increase in savings is 16.5ppts.
Measure II: Present value of potential savings

- Consider a mortgage originated at date $\tau$ with a fixed interest rate $r^{old}$ and maturity $T$.
- We compute the benefits from refinancing at time $t$

\[
\text{Balance}_t = \sum_{k=1}^{\tau+T-t} \frac{\text{Payment}}{(1 + r)^k}
\]

\[
\text{Savings}_t = \sum_{k=1}^{\tau+T-t} \frac{\text{Payment}^{old} - \text{Payment}^{new}}{(1 + r^{new})^k}
\]

- $\text{Savings}_t > 0$: consumer saves on interest payments by refinancing.
- $\text{Savings}_t < 0$: consumer has higher interest payments if they refinanced.
State variables

- One specific process we consider is:

\[
S_t = a_0 + a_1 S_{t-1} + a_2 \psi_{t-1} + a_3 S_{t-1} \cdot \psi_{t-1} + u_t
\]

\[
\psi_{t-1} = b_0 + b_1 S_{t-1} + b_2 \psi_{t-1} + b_3 S_{t-1} \cdot \psi_{t-1} + \nu_t
\]

where \( S = [\log y, \log(p), \log(r)] \) and \( \psi \) is the log average positive savings.

- Estimate coefficients using the data. Performs reasonably well in its mean-squared forecast error.

- Decompose residuals \([u_t, \nu_t] = \Gamma(\epsilon_t) + \nu_t\). Estimate \( \Gamma \) using high-frequency monetary policy shocks in the data.
VAR response to monetary shock

- Change in income (% annualized)
- Change in interest rate (ppts)
- Change in house prices (% annualized)
- Change in average positive savings (%)
**Labor income**

**Table: Income Exposure to Aggregate Activity by Age**

<table>
<thead>
<tr>
<th>Age group</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>55-64</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_a$</td>
<td>4.582</td>
<td>1.603</td>
<td>3.574</td>
<td>0.307</td>
</tr>
</tbody>
</table>

**Notes:** This table shows the estimated coefficient $\phi_a$ for each age group $a$. This is obtained from an regression of the log earnings growth of each group on log growth in aggregate income per capita interacted with an indicator function for the 10-year age ranges, controlling for age-education-gender fixed effects, quarterly seasonality and a linear time trend. The regression is based on quarterly CPS data over 1982-2007.
Distribution of potential savings in 1997 and 2000
Household model: set-up

1. Life-cycle

2. Idiosyncratic income risk and aggregate shocks

3. Assets: - liquid one-period asset
   - illiquid housing and fixed rate mortgage

4. Fixed cost of adjusting the mortgage and housing
   - $F$: calibrated to match average refi rate.

5. Borrowing constraints: short-term constraint; mortgage LTV constraint
Demographics and preferences

- Households can live up to $T = 60$ periods: Work for 40, retired for 20. Probability of survival $\pi_a$.

- Preferences

$$\left( c_{jat}^{\alpha} \cdot h_{jat}^{1-\alpha} \right)^{1-\sigma} - 1$$

Bequest motive

$$B \left( W_{jat}^{1-\sigma} - 1 \right) / (1 - \sigma)$$
Labor income

- Labor income process for household $j$ of age $a$ at time $t$:
  \[
  \log (y_{jat}) = \chi_a + \eta_{jat} + \phi_a(Y_t)
  \]
  \[
  \chi_a = \text{age-dependent component and } \eta_{jat} = \text{idiosyncratic component}
  \]
  \[
  \eta_{jat} = \rho \eta_{j,a-1,t-1} + \psi_{jt}
  \]

- Retirement income modeled as in Guvenen and Smith (2014).
Household $j$ who enters a loan at age $a$ in date $0$:

- Has a fixed rate $R_{ja0}$ and payment $M_{ja0}$.

- Principal evolves as: $b_{j,a+1,t+1} = b_{jat}(1 + R_{ja0}) - M_{ja0}$.

- Mortgages are amortized over remaining life of the individual.

- Maximum allowable mortgage: $b_{ja0} \leq (1 - \phi) p_{0} h_{ja0}$.

- Fixed cost $F$ applies to refinancing and new loans.
Borrowing constraints

Short-term asset constraint

\[ s' \geq 0 \]

Mortgage constraint

\[ b' \geq -(1 - \phi)ph' \]

which applies if loan is new or refinanced
Value function and budget constraints

\[ V(z) = \max \{ V(z)^{\text{own} \& \text{adjust}}, V(z)^{\text{own} \& \text{noadjust}}, V(z)^{\text{rent}} \} \]

where

\[ V(z)^k = \max u(c, h^k) + \beta E[V(z')] \quad \text{s.t.} \]

▶ if own home and adjust loan:

\[ c + s' - b' + b(1 + R) + p[h'^o - (1 - \delta)h^o] = y + (1 + r)s - F \]

where \( R' = r \)

▶ if own home and do not adjust loan:

\[ c + s' = y + (1 + r)s - M \]

where \( h'^o = (1 - \delta)h^o \) and \( R' = R \)

▶ if rent:

\[ c + s' + p^r h^r = y + (1 - \delta)p h^o + (1 + r)s - b(1 + R) \]
## Aggregate processes: coefficients

<table>
<thead>
<tr>
<th>Variables</th>
<th>30-year rate&lt;sub&gt;t&lt;/sub&gt;</th>
<th>log rental rate&lt;sub&gt;t&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>log y&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td>-3.475***</td>
<td>0.843***</td>
</tr>
<tr>
<td></td>
<td>(0.168)</td>
<td>(0.119)</td>
</tr>
<tr>
<td>log r&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td>0.334***</td>
<td>-0.002***</td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>log p&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td>-0.022</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>-0.030</td>
<td>3.187***</td>
</tr>
<tr>
<td></td>
<td>(15.82)</td>
<td>(0.488)</td>
</tr>
</tbody>
</table>
Actual and fitted log house prices-to-rent ratio

Log House Price to Rent Ratio

- Actual
- Fitted


State Dependent Effects of Monetary Policy: The Refinancing Channel
Owning versus renting

- Net benefit of owning a home:

\[
\frac{p_t^r}{p_t} + E_t \frac{p_{t+1} - p_t}{p_t} - r_t \left(1 - \frac{b_t}{p_t}\right) - \frac{b_t}{p_t} r_t^m - \delta - r_t \frac{F}{p_t}.
\]

- The higher the rental-price ratio and the expected real rate of housing appreciation, the more attractive it is to own.

- The cheaper the house, the larger the negative impact of a fixed cost the less attractive it is to own \((r_t F / p_t)\).

- The higher the down payment the household can make, the more attractive it is to own. Opportunity cost of the down payment and the mortgage payment:

\[
r_t + \frac{b_t}{p_t} \left(r_t^m - r_t\right).
\]