State Dependency of Monetary Policy: The Refinancing Channel

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Motivation

- In the U.S., the bulk of household borrowing is in fixed rate mortgages with a refinancing option.
- The decision to refinance depends on the potential interest savings relative to any costs involved.
- The distribution of potential interest savings changes over time.
- These changes imply that the effects of monetary policy on refinancing are time-varying and state dependent.

Document state dependency of monetary policy

- Distribution of rate gap and potential savings varies over time.
- Refinancing response is larger when potential savings are higher:
  - Fraction of loans refinanced is larger.
- Response of the real economy to a rate cut is larger:
  - e.g. housing permits rise by more.
- Therefore, the effects of monetary policy are state-dependent.

Structural quantitative analysis

- Objectives:
  - Study different paths of monetary policy.
  - Study the impact of historical lower transaction costs on the efficacy of monetary policy.
- We do this in a heterogeneous agents model with costly refinancing.

Objective I: Study different paths of monetary policy

- We find that a given interest rate cut is less powerful when it's proceeded by a sequence of rate hikes.
  - Intuition: when rate are rising, many consumers have existing fixed rates that are lower than the current market rate.
- We find that a given interest rate cut is more powerful when it's proceeded by a sequence of rate cuts.
  - Intuition: when rate are falling, many consumers have existing fixed rates that are higher than the current market rate.

Objective II: Study historical impact of lower transaction costs

As transaction costs fall:

- State-dependent effects of monetary policy decrease:
  - Average gains from refinancing are smaller, because consumers refinance more often so existing rates are closer to the current market rate.
  - The distribution of potential savings across consumers varies less over time.
- The aggregate impact of a given interest rate cut becomes larger:
  - Consumers are more likely to refinance, so interest rate reductions pass through to more consumers.
  - Effects on consumption are particularly powerful if the consumers who refinance have high MPCs (face binding borrowing constaints, or are wealthy "hand-to-mouth" consumers).

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. Summary stats

Data

1. Define key concepts that are correlated with potential interest savings from refinancing.

2. Describe the distribution of potential savings and evolution over time.

3. Estimate the implications for refinancing decisions.

Data: Measuring potential interest savings

- Potential savings depends on old and new mortgage rates, outstanding balances, and the household's refinancing strategy.
- We consider two measures of potential savings:
  1. Simple interest rate gap relative to current mortgage rate;
  2. Present value of potential savings;
- In general, not sufficient statistics. But they are highly correlated with refinancing, and easy to compute in the data and model.

Measure I: Simple interest rate gap

For each individual i at time t

$$r_{it}^{\text{gap}} = r_{it}^{\text{old}} - r\left(\text{FICO}, \text{region}\right)_{it}^{\text{new}}$$

- r_{it}^{old} is consumer i's existing mortgage rate.
- $r\left(\text{FICO}, \text{region}\right)_{it}^{\text{new}}$ is the current rate on new loans issued for the same FICO score range in the same region as consumer i.
  - It is an estimate of the new rate if they refinanced.
  - We consider the FICO score bins: below 600, 600-620, 620-640,... ,760-780, greater than 780.

Measure I: Simple interest rate gap

$$r\left(\text{FICO}, \text{region}\right)_{it}^{\text{gap}} = r_{it}^{\text{old}} - r\left(\text{FICO}, \text{region}\right)_{it}^{\text{new}}$$

- $r_t^{\text{gap}} > 0$: consumer can save and pay a lower rate by refinancing.
- $r_t^{\text{gap}} < 0$: consumers pay a higher rate if they refinanced.
- Also compare to a refinancing threshold, Agarwal, Driscoll and Laibson (2013). More details
  - Real interest rate and inflation are Brownian motions.
  - Constant real value of mortgage until an endogenous refinancing event or an exogenous Poisson repayment event.

Measure II: Present value of potential savings

- Our second measure of potential savings from refinancing is the present value of gains from the following refinancing strategy:
  - The existing loan is refinanced with a FICO-specific 30-year fixed-rate mortgage.
  - The new loan is repaid over the remainng life of the existing mortgage.

Measure II: Present value of potential savings

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

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

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

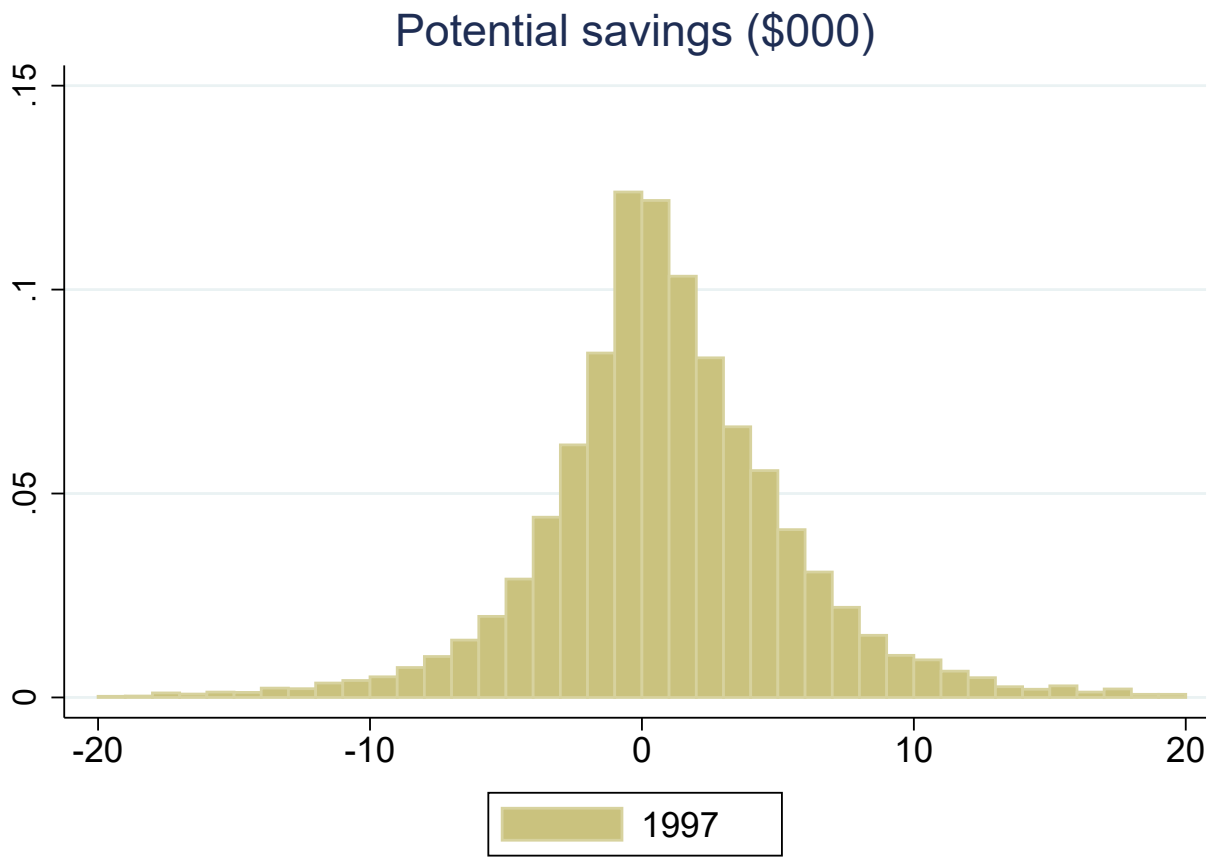
  - $\text{Savings}_t > 0$: consumer saves on interest payments by refinancing.
  - $\text{Savings}_t < 0$: consumer has higher interest payments if they refinanced.

Distribution of interest rate gaps in 1997



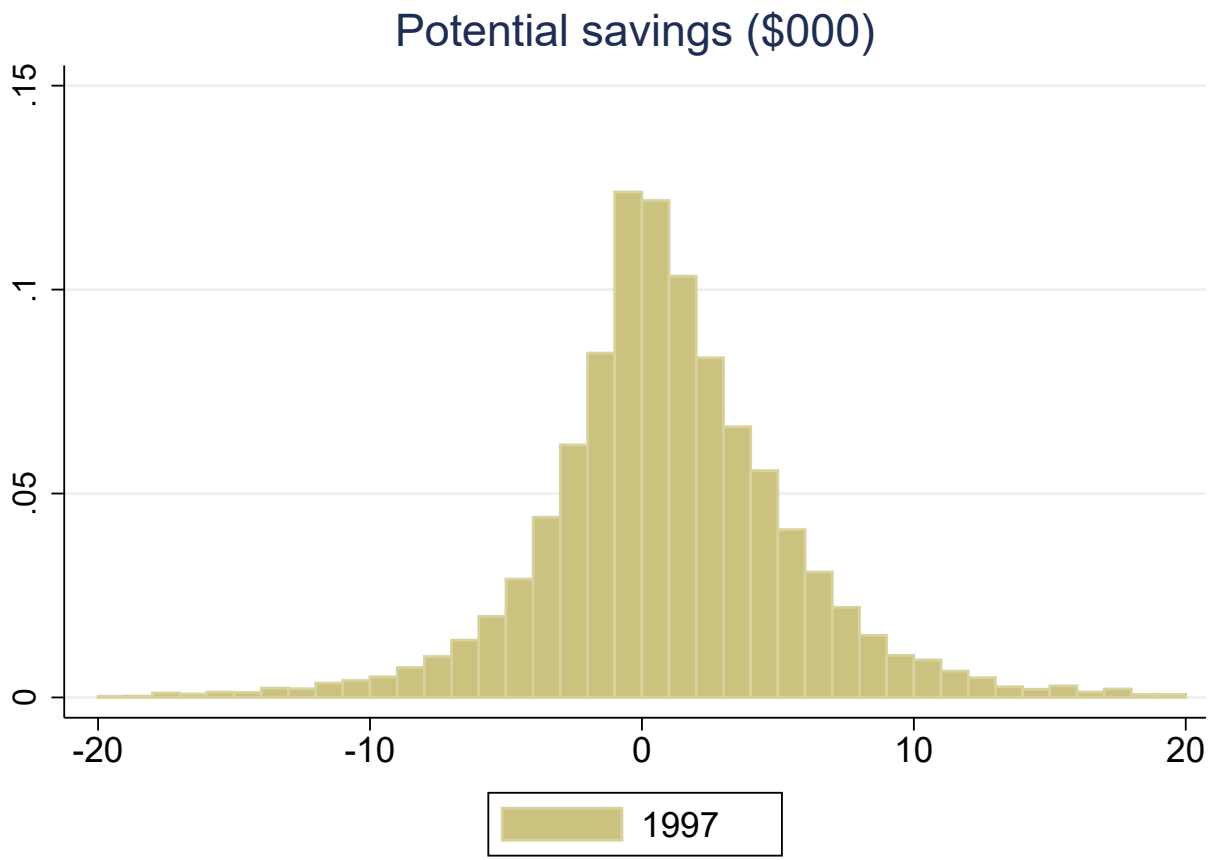
- In 1997, about 60% of mortgages had a positive rate gap. The average rate gap was 10bps.

Distribution of potential savings in 1997



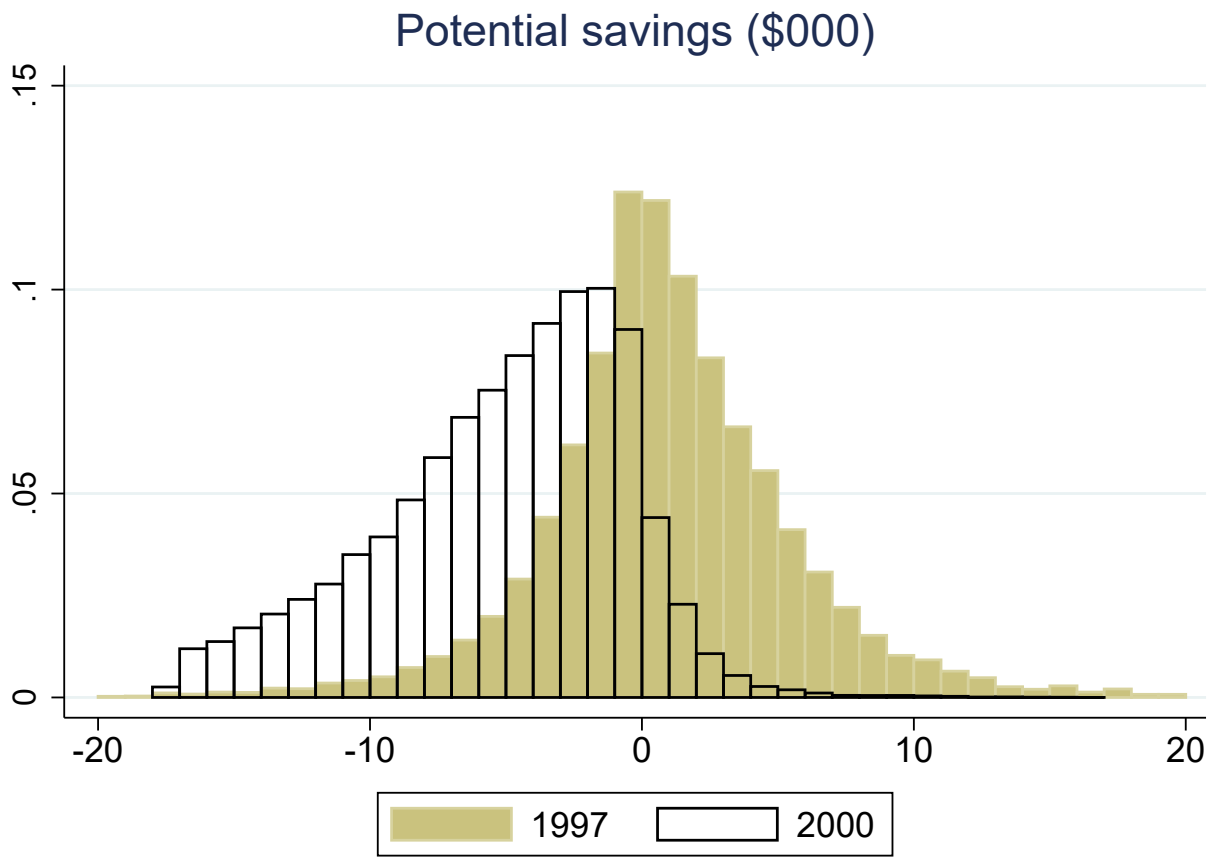
- In 1997, about 60% of mortgages had positive potential savings, with average positive savings of $3,700.

Distribution of potential savings in 1997



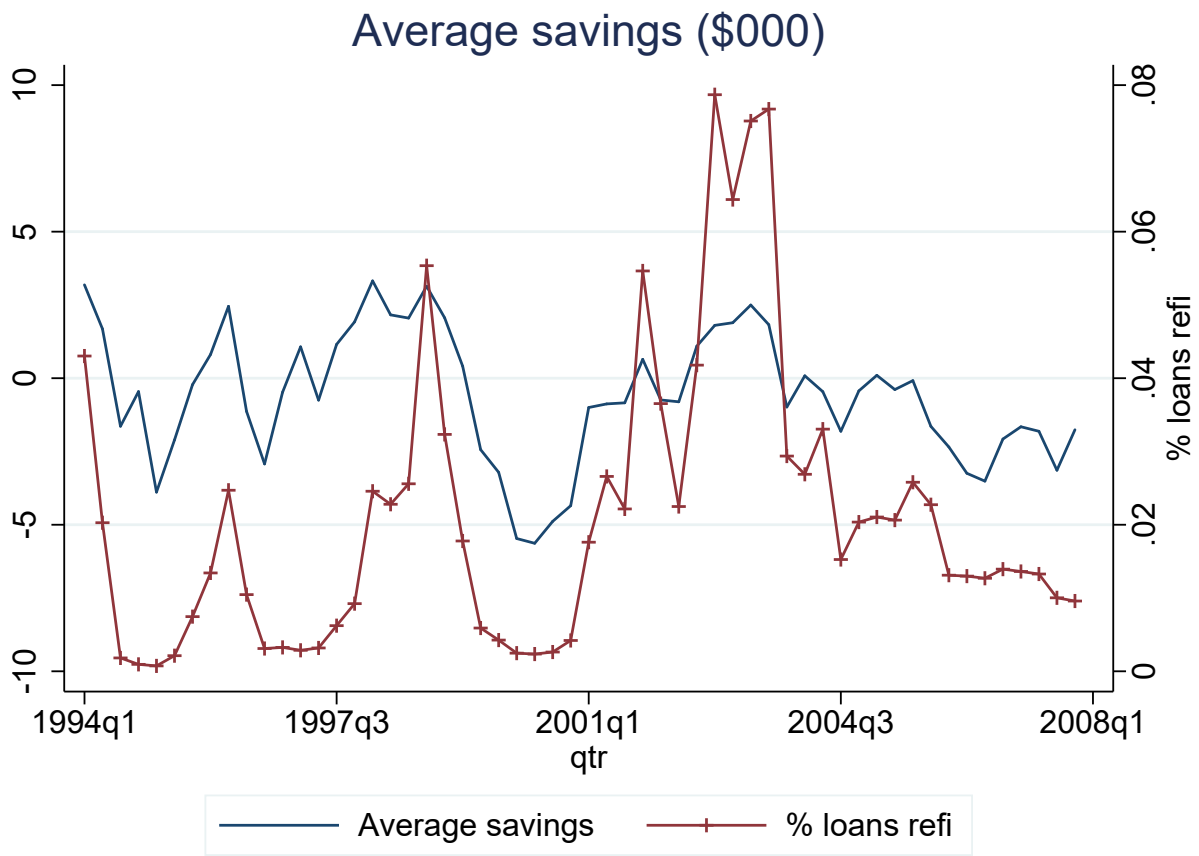
- Declines in the current mortgage rate will shift the distribution to the right, all else equal. We will see this leads to more refinancing.

Distribution of potential savings in 1997 and 2000



- In 1997, about 60% of mortgages had positive potential savings, with average savings of $3,700. In 2000, about 10% of mortgages had a positive rate gap, with average savings of $1,600. More

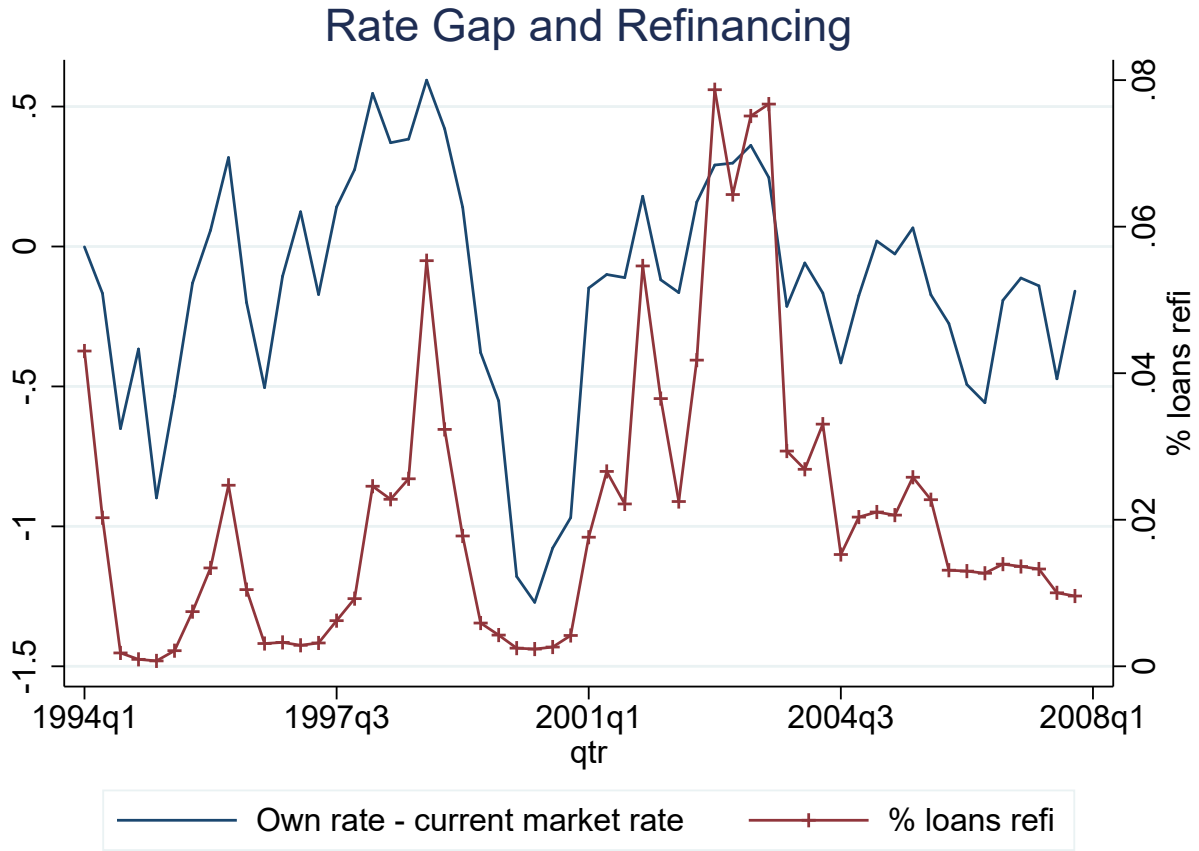
Refinancing and average savings



- Correlation between refinancing and average savings of 0.62.

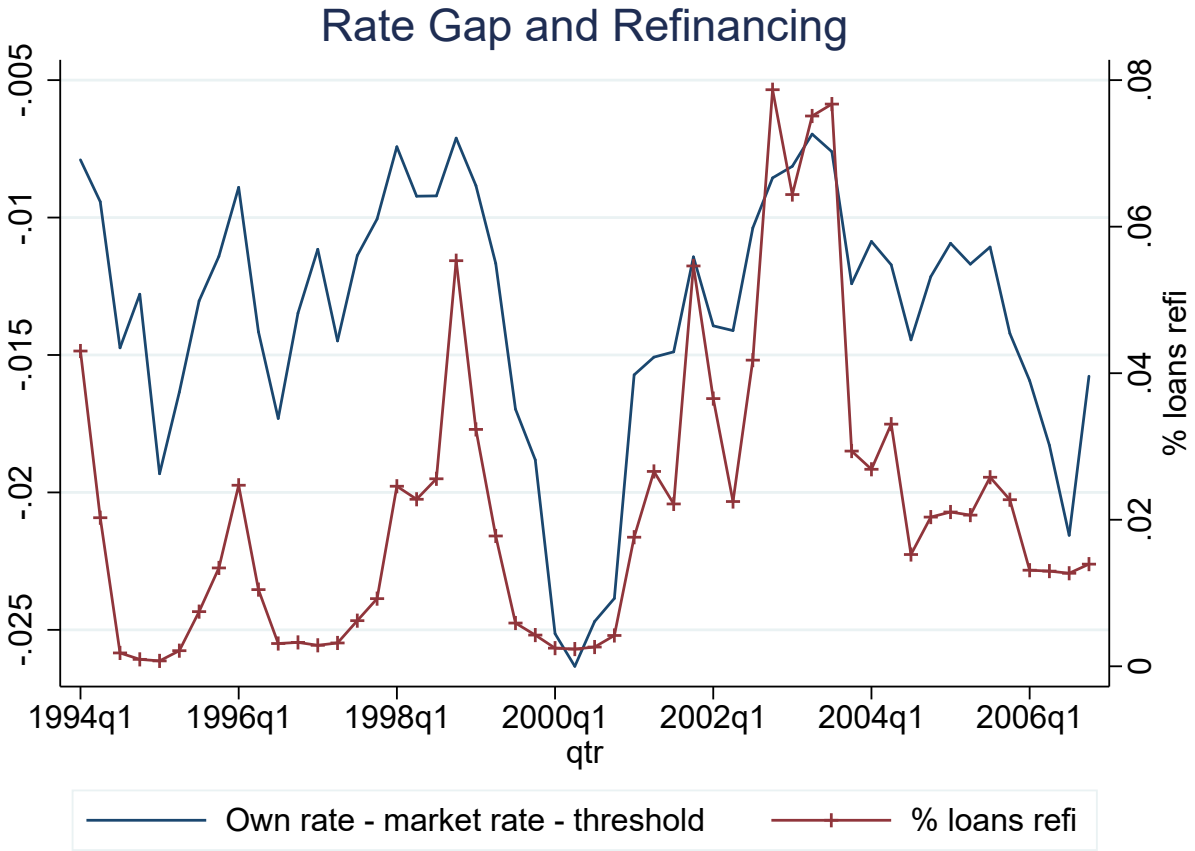
Real mortgage rate | Post 2007

Refinancing and average interest rate gap



- Correlation between refinancing and average interest rate gap is 0.65.

Refinancing and the gap above the ADL threshold



- Correlation between refinancing and interest gap above the ADL threshold is 0.63.

State dependency and the efficacy of monetary policy

- Distribution of potential interest savings changes over time.
- More refinancing when potential savings in the period is higher.
- What does this imply for the transmission of monetary policy on refinancing activity over time?

State dependency and the efficacy of monetary policy

For county c in quarter t, we estimate

$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi(savings)_{c,t-1} + \beta_3 \psi(savings)_{c,t-1} + \beta_4 X_{ct} + \lambda_c + \eta_{ct}.$$

where

- $\rho_{c,t+4}$ is the fraction of loans that refinance over the year,
- ΔR_t^M is the change in mortgage rate offered in the market,
- $\psi(savings)_{c,t-1}$ is a moment of the existing distribution
  - average rate gap,
  - average potential savings.
- X_{ct} denotes the county-level demographic variables, including house prices, unemployment rate.

State dependency and the efficacy of monetary policy

For county c in quarter t, we estimate

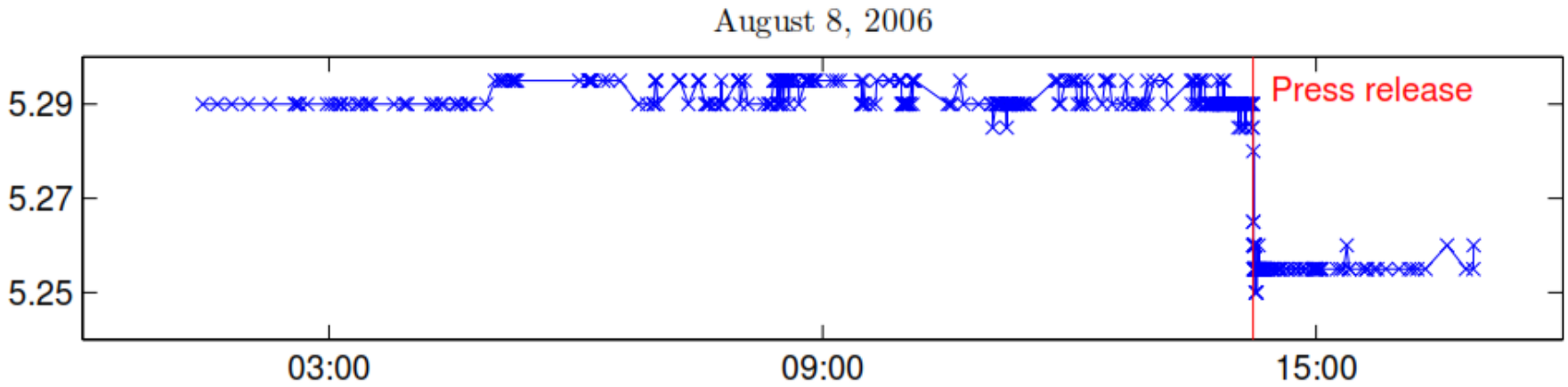
$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi(savings)_{c,t-1} + \beta_3 \psi(savings)_{c,t-1} + \beta_4 X_{ct} + \lambda_c + \eta_{ct}.$$

Potential challenges to identification:

- Shocks and unobservable variables affecting both refinancing propensities and mortgage rates.
- Instrument using high frequency data on Federal Funds futures and Treasury yields, and its interactions with $\psi(savings)_{c,t-1}$.

Monetary policy shocks

Shock measured using Fed Funds futures and 2-year Treasuries.



Source: Gorodnichenko and Weber (2015)

Approach used in Kuttner (2001), Rigobon and Sacks (2004), Nakamura and Steinsson (2013), Gorodnichenko and Weber (2015), Gertler and Karadi (2015), etc. Shocks

State dependency: Average rate gap

For county c in quarter t, we estimate

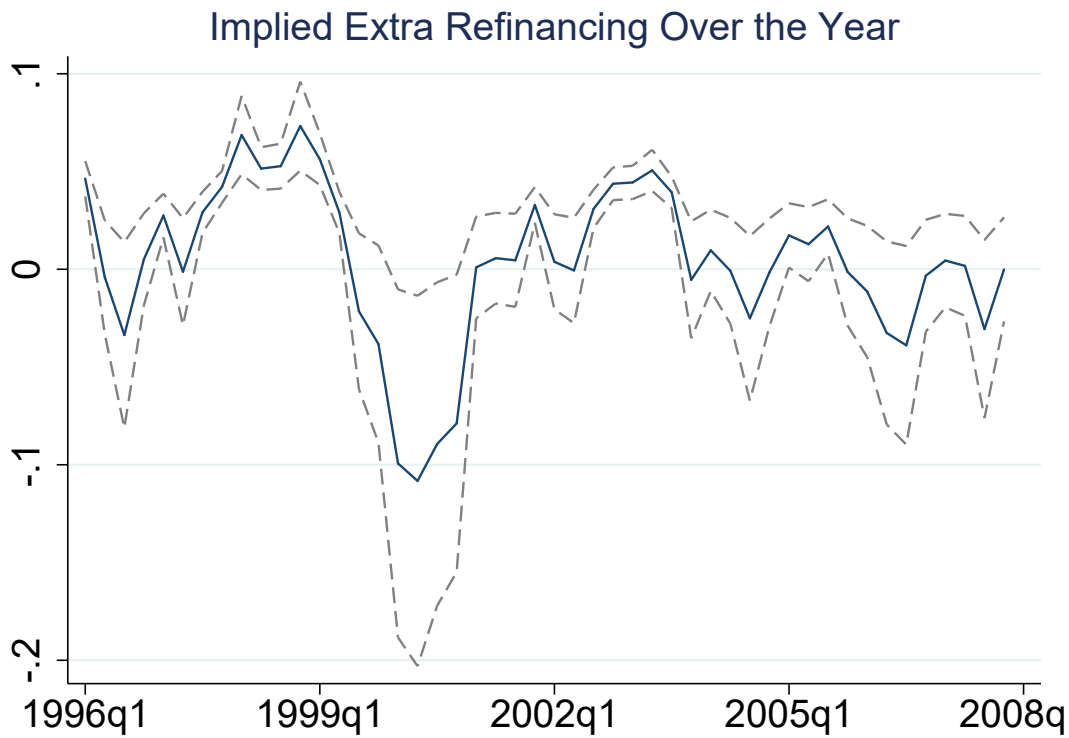
$$\rho_{c,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.$$

	OLS	IV using	
	Mortgage rate	Futures	Δ2yr Treasury
	(I)	(II)	(III)
ΔR(t)	0.075***	0.062***	0.195***
	(0.004)	(0.021)	(0.032)
ΔR(t) x Average rate gap	0.039**	0.389***	0.244**
	(0.014)	(0.075)	(0.101)
County Fixed Effects	Yes	Yes	Yes
SPF Controls	No	No	No
Additional county controls	No	No	No

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.
- Marginal impact of a 1sd increase in rate gap is 6.8 ppts. 1st st III

Refinancing rate response to 25bps expansionary shock



$$\beta_1 \triangle R_t + \beta_2 \triangle R_t \times (\text{Average rate gap})_t$$

- The implied marginal effect of a 25bp cut ($\triangle R_t$) on refinancing from column II. Sizable effects, compared to an unconditional average rate of about 8.5%. Savings

State dependency: Average rate gap

For county c in quarter t, we estimate

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

	OLS	IV using					
	Mortgage rate	Futures	Δ2yr Treasury	Futures	Δ2yr Treasury	Futures	Δ2yr Treasury
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
ΔR(t)	0.075***	0.062***	0.195***	0.070*	0.267***	0.083***	0.396***
	(0.004)	(0.021)	(0.032)	(0.029)	(0.026)	(0.026)	(0.075)
ΔR(t) x Average rate gap	0.039**	0.389***	0.244**	0.479***	0.364***	0.472***	0.637***
	(0.014)	(0.075)	(0.101)	(0.109)	(0.106)	(0.102)	(0.275)
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	No	Yes	Yes

- Results are robust to including additional controls, such as SPF expectations (IV)-(V) and county controls (house prices, unemployment, manufacturing share, age, edu) (VI)-(VII). More

State dependency: Other moments

- Average positive savings. More
- Fraction of loans with positive savings.
- Fraction of loans above the ADL threshold. More
- Median, standard deviation, skewness.

Real outcomes: building permits

- Monthly data from Census Building Permits Survey, aggregated to quarterly frequency.
- Permits required for new privately-owned residential buildings. It is a leading economic indicator.
- County-level data available from 2000 onward.

Real outcomes: building permits and average rate gap

For county c in quarter t, we estimate

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

	OLS		IV using				
	Mortgage rate (I)	Futures (II)	Δ2yr Treasury (III)	Futures (IV)	Δ2yr Treasury (V)	Futures (VI)	Δ2yr Treasury (VII)
ΔR(t)	0.175***	0.396***	0.265***	0.356***	0.236***	0.083***	0.396***
	(0.019)	(0.034)	(0.034)	(0.036)	(0.029)	(0.026)	(0.075)
ΔR(t) x Average rate gap	0.083**	0.373***	0.151**	0.111*	0.187**	0.472***	0.637
	(0.021)	(0.103)	(0.099)	(0.076)	(0.080)	(0.102)	(0.275)
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	No	Yes	Yes

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

- If rate gap is -14bp (mean), permits growth rate +8.5ppts.
- If rate gap is 56bps (mean+1sd), permits growth rate +15.07ppts.
- Marginal impact of a 1sd increase in rate gap is 6.5 ppts. Savings

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 costs of adjusting the mortgage and housing
5. Borrowing constraints: short-term constraint; mortgage constraint

Demographics and preferences

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

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

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:

$$\log(y_{jat}) = \chi_{ja} + \eta_{jat} + \phi_a(y_t/y)$$

χ_{ja} = age-dependent component and η_{jat} = idiosyncratic component

$$\eta_{jat} = \rho_\eta \eta_{j,a-1,t-1} + \psi_{jt}$$

- Retirement income modeled as in Guvenen and Smith (2014).

Structure of fixed-rate mortgages

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.

Value function

Value function of household with state set z (suppressing j and t):

$$V(z) = \max u(c, h') + \beta E\left[V(z')\right]$$

where

$$h' = h^r 1(rent) + h'^o \left(1 - 1(rent)\right)$$

Choice variables

- Housing: $1(rent)$ and if so h^r
- Loan adjustment: b' and h'^o
- Other: c and s'

States

- Individual states: a, s, h^o, b, R, y
- Aggregate states: S

Budget constraints

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

- if own home and adjust loan:

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

$$\text{where } R' = r^{d(a)}$$

- if own home and do not adjust loan:

$$c + s' = y + (1+r)s - M$$

$$\text{where } h'^{o} = (1-\delta)h^{o} \text{ and } R' = R$$

- if rent:

$$c + s' + p^{r}h^{r} = y + (1-\delta)ph^{o} + (1+r)s - b(1+R)$$

Borrowing constraints

Short-term asset constraint

$$s' \geq -\underline{s}$$

Mortgage constraint

$$b' \geq -(1-\phi)ph'^{o}$$

which applies if loan is new or refinanced

Exogenous aggregate state variables

- Aggregate state process:

$$S_t = A_0(\psi_{t-1}) + A_1(\psi_{t-1}) \cdot S_{t-1} + u_t$$
$$\psi_{t-1} = B_0(\psi_{t-1}) + B_1(\psi_{t-1}) \cdot S_{t-1} + \nu_t$$

  where $S = [\log y, \log(p), \log(r)]$ and ψ is a moment(s) of the savings distribution.

- Coefficients can be a function of the savings distribution, capturing the state-dependency in the data.

Exogenous aggregate 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 ψ is the log average positive savings.

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

- Decompose residuals $[u_t, v_t] = \Gamma(\epsilon_t) + \nu_t$. Estimate Γ using high-frequency monetary policy shocks in the data. Coefficients

Exogenous aggregate state variables

- Mortgage rate on a d period loan

$$r^d = \alpha_{0,d} + \alpha_{1,d} r + \alpha_{2,d} y$$

- Rental rate

$$log(p^R) = \lambda_0 + \lambda_1 r + \lambda_2 y + \lambda_3 \log(p)$$

Actual vs fitted series Coefficients

Model calibration

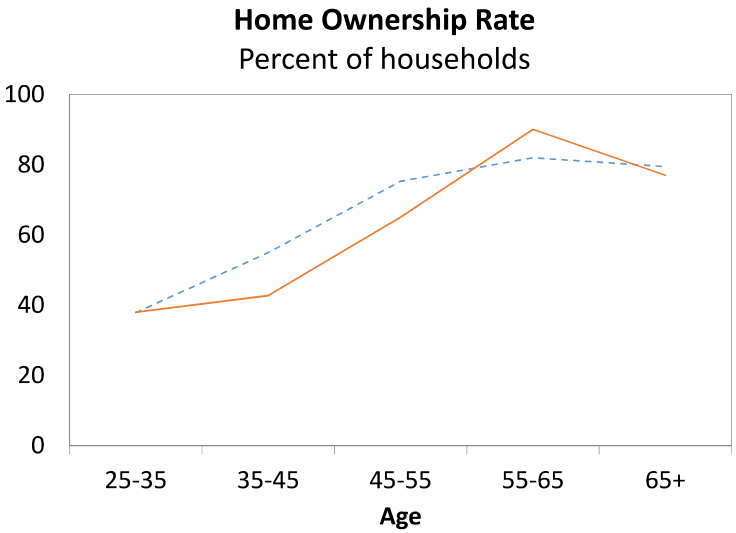
Exogenously set parameters:

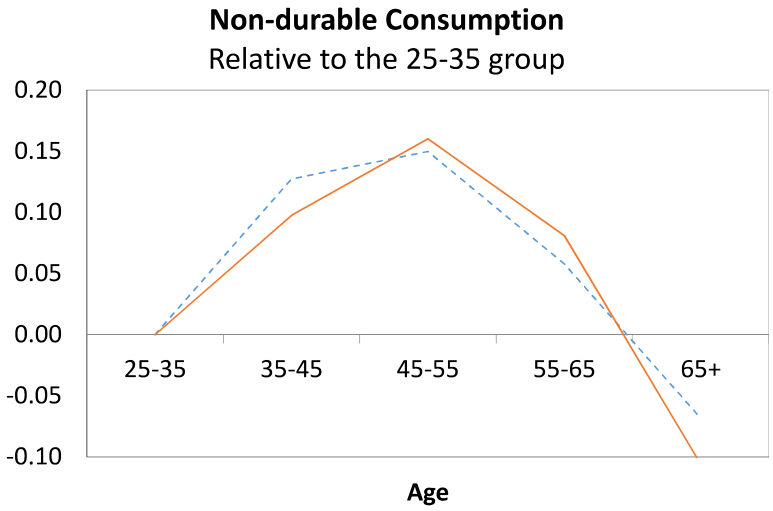
- Model is annual
- Intertemporal elasticity $\sigma = 2$
- Housing depreciation rate $\delta = 3\%$
- Collateral constraint $\phi = 0.2$
- Income process with $\rho = 0.91, \sigma_y = 0.21$ (Hurst et al, 2014)
- Income exposure to aggregate shocks: ϕ_a from CPS

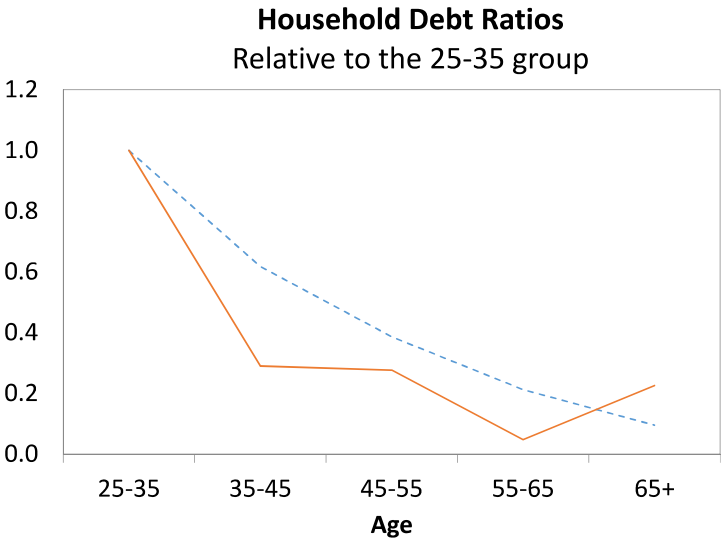
Calibrated parameters:

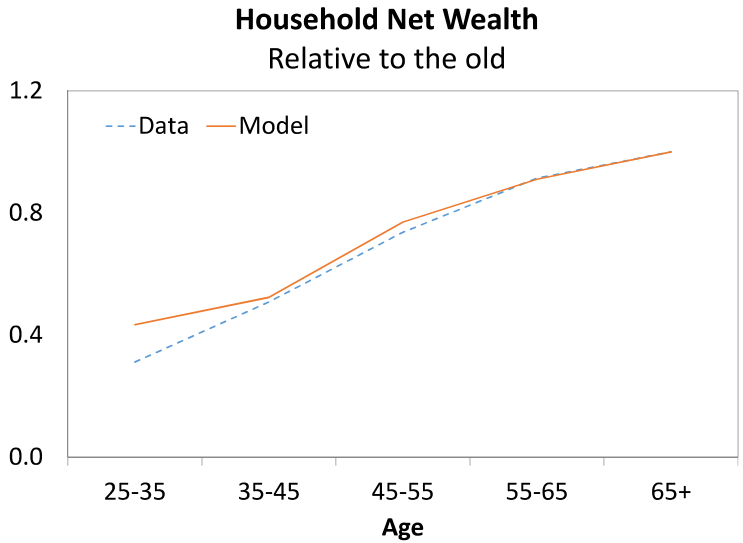
- Utility parameter $\alpha = 0.88$ and discount rate $\beta = 0.962$ chosen to match $W/Y = 2.3$ and homeownership rate $= 66\%$.
- $F =$ approximately $2.1K$ (2% of median house price) chosen to match average quarterly fraction of new loans of 4.5%.

Model fit: life-cycle moments





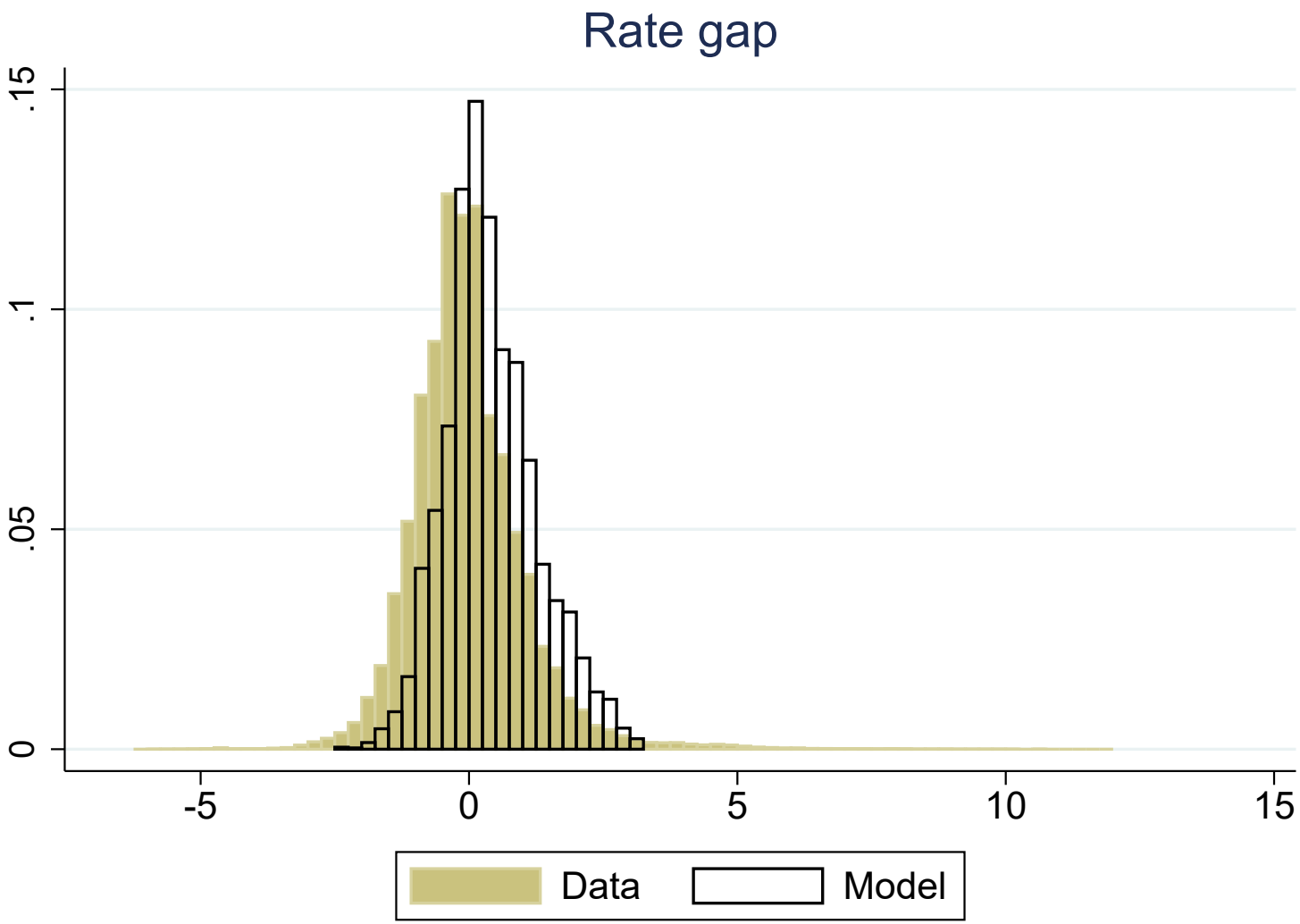




Model fit: state dependency of monetary policy

- Start the simulation in 1994, where agents have the distribution of assets, liabilites and mortgage rates that we observe in the data.
- Feed in actual prices and real variables from 1995 to 2007.
- Compute household's decisions.

Model fit: mortgage rate gap distribution (1995-2007)



- Correlation between average rate gap in the model and data is

Model fit: state dependency of monetary policy

- Compute the same regressions within the model, given the agents' choices:

Average rate gap	Data		Model	
	IV using		IV using	
	Futures	Δ2yr Treasury	Futures	Δ2yr Treasury
ΔR(t)	0.062***	0.195***	0.038	0.006
	(0.021)	(0.032)		
ΔR(t) x Average rate gap	0.389***	0.244**	0.299	0.243
	(0.075)	(0.101)		

- Again we see larger refinancing response to a rate cut when the initial rate gap is larger. Bins

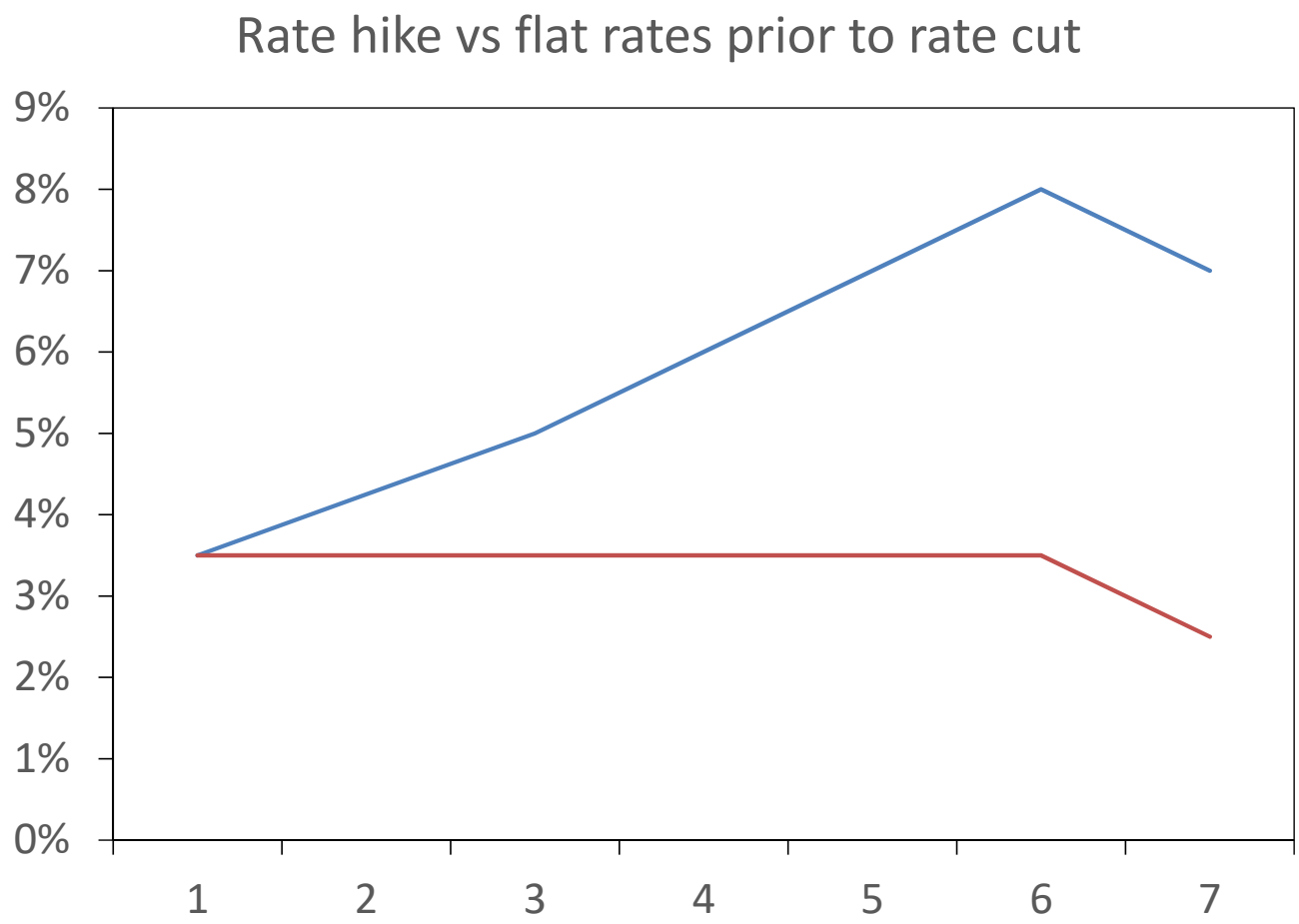
State dependency of monetary policy

To highlight the state dependency of monetary policy, consider the effect of a 1ppt rate cut following:

- a sequence of rate hikes vs. maintaining a constant rate
- a sequence of deep rate cuts vs a shallow rate cut cycle

Aggregate variables

Experiment I: Alternative interest rate paths



Expectations

Experiment I: Alternative interest rate paths

	Rate path prior to a 1 ppt cut	Average rate gap before cut	Fraction with positive rate gap, after rate cut	Effect on refinancing	Change in consumption
(i)	Flat at about 3.5%	0.00%	100%	25%	2.39%
(ii)	Rising from 3.5% to 8% over 5 periods	-1.12%	26%	3%	0.28%

- Rate hikes prior leads to lower refinancing to future rate cuts.

Experiment II: Lower transaction costs

	Fixed cost	
	\$2.1K	\$1K
Effect on refinancing:		
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(φ_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(φ_t)	0.42%	0.36%

Lower transaction costs lead to:

- Higher overall response to lower rates, given an initial rate gap
- Less state-dependency (marginal effects of a higher rate gap). 2yrT

Conclusion

- There is substantial variation in the distribution of rates and potential savings from refinancing over time.
- The refinancing response depends on the distribution of rates.
- The effect of monetary policy depends on the distribution of rates and potential savings at the time of the rate cut:
  - Rate hikes prior leads to lower refinancing to future rate cuts.
  - Deeper rate cuts in the past leads to lower refinancing responses to future rate cuts.

Spare slides

Interest rate gap relative to ADL refinancing threshold

- Optimal refinancing solution depends on the discount factor, closing costs, mortgage size, the marginal tax rate, the standard deviation of the innovation in the mortgage interest rate, and the Poisson rate of exogenous real repayment.
- Anderson, Campbell, Nielsen and Ramadora (2015) apply the ADL threshold model to Danish mortgage market.
  - Study role of unobservable heterogeneity, inattention and inertia in refinancing decisions in the Danish mortgage market.

Interest rate gap relative to ADL refinancing threshold

Under ADL's assumptions, the optimal refinancing rule is as follows:

- Refinance if:

$$r_{it}^{\text{old}} - r\left(\text{FICO}, \text{region}\right)_{it}^{\text{new}} > \frac{1}{\psi}\left[\phi + W(-exp(-\phi))\right]$$

- $W(.)$ is the Lambert W-function,

$$\psi = \frac{\sqrt{2(\rho+\lambda)}}{\sigma}$$

$$\phi = 1 + \psi(\rho+\lambda)\frac{\kappa/M}{(1-\tau)}$$

- ρ = real discount rate, λ = expected real rate of exogenous mortgage repayment, σ = sdt of mortgage rate, κ/M = ratio of tax-adjusted refinancing cost and remaining mortgage value, and τ = marginal tax rate.

Interest rate gap relative to ADL refinancing threshold

- Refinancing cost

$$\kappa = F + fM\left[1 - \frac{\tau}{\theta+\rho+\pi}\left[\left(\frac{1-e^{-(\theta+\rho+\pi)N}}{N}\right)\left(\frac{\rho+\pi}{\theta+\rho+\pi}\right)+\theta\right]\right]$$

where F and f are the fixed and variable costs, respectively. The term in the brackets reflects the PV of future tax deductions of the variable costs.

- $\theta \equiv \mu + 0.1$ denotes the expected arrival of a full deductibility event (moving or subsequent refinancing). π is inflation, ρ is discount rate, N is length of new loan, M is mortgage balance.

- Expected repayment rate of the mortgage λ satisifes

$$\lambda M = \mu M + (p - i_0 M) + \pi M$$

where M is the real mortgage balance, p is the mortgage repayment, i_0 is the interest rate, and π is the inflation rate.

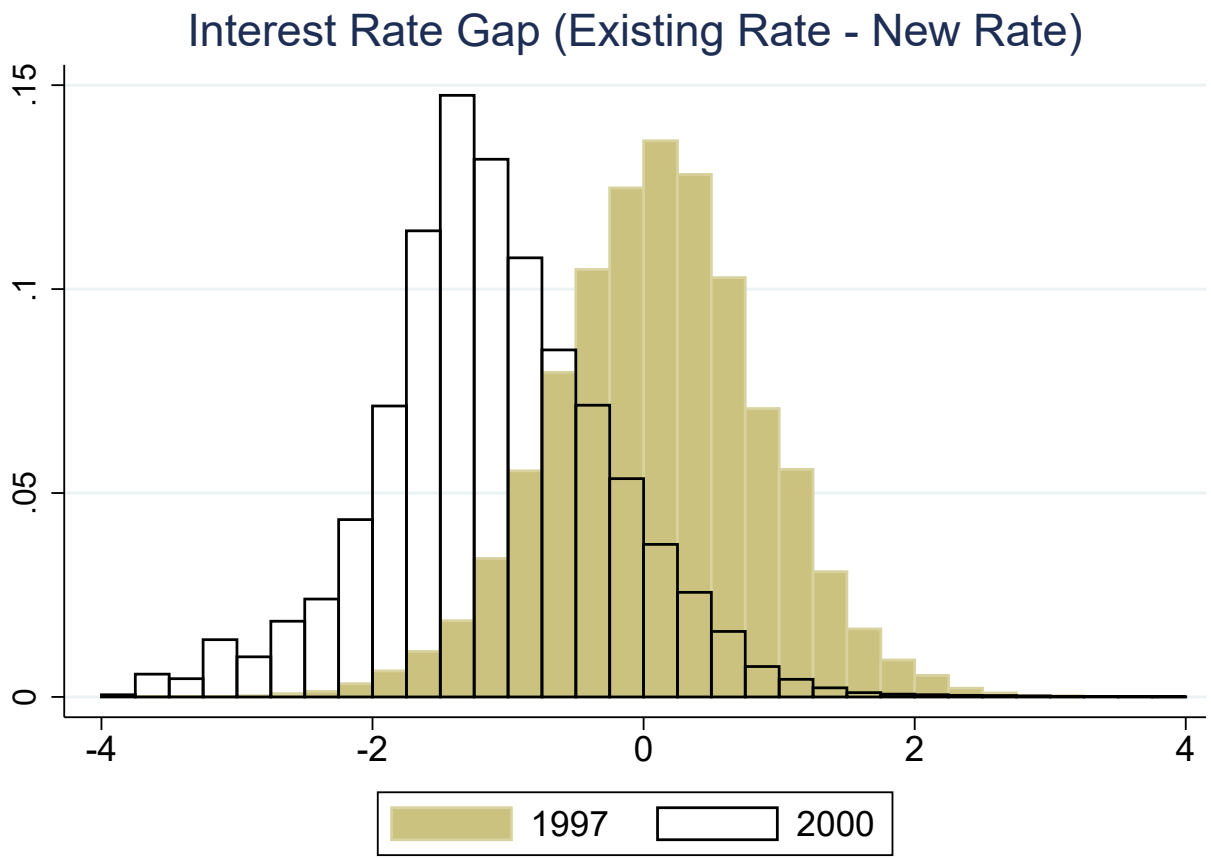
Interest rate gap relative to ADL refinancing threshold

- Key parameters from ADL:

Parameter		Value
ρ	Real discount rate	0.05
τ	Marginal tax rate	0.28
σ	Annualized standard deviation of mortgage rate	0.0109
N	Number of years on a new mortgage	30
μ	Probability of moving	0.1
f	Variable transaction costs (% balance)	0
F	Fixed transaction costs	1000

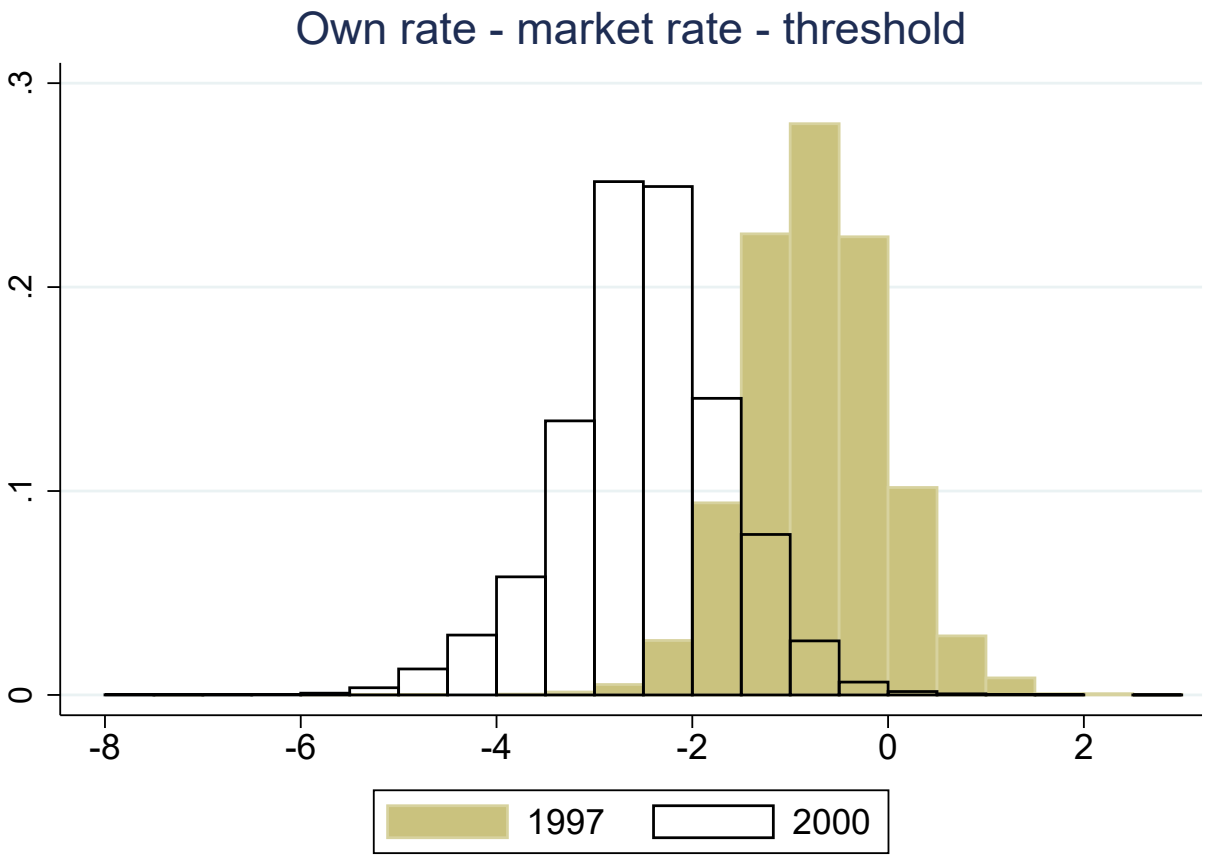
- Data on balances and interest rates from Core Logic. Data on expected inflation from the Federal Reserve Bank of Cleveland.

Distribution of interest rate gaps in 1997 and 2000



- In 1997, about 60% of mortgages had a positive rate gap. In 2000, about 10% of mortgages had a positive rate gap. Back

Distribution of ADL gaps in 1997 and 2000



- In 1997, about 10% of mortgages fell above the ADL threshold, compared with 0.2% of mortgages in 2000. Back

State dependency: Average savings

For county c in quarter t, we estimate

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

	OLS			IV using			
	Mortgage rate (I)	Futures (II)	Δ2yr Treasury (III)	Futures (IV)	Δ2yr Treasury (V)	Futures (VI)	Δ2yr Treasury (VII)
ΔR(t)	0.074***	0.103***	0.186***	0.130***	0.286***	0.142***	0.398***
	(0.003)	(0.013)	(0.020)	(0.013)	(0.023)	(0.013)	(0.041)
ΔR(t) x Average savings	0.013***	0.048***	0.067***	0.059***	0.096***	0.056***	0.144**
	(0.002)	(0.009)	(0.013)	(0.008)	(0.019)	(0.009)	(0.033)
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	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.

Back 1st st

State dependency: Gap above ADL threshold

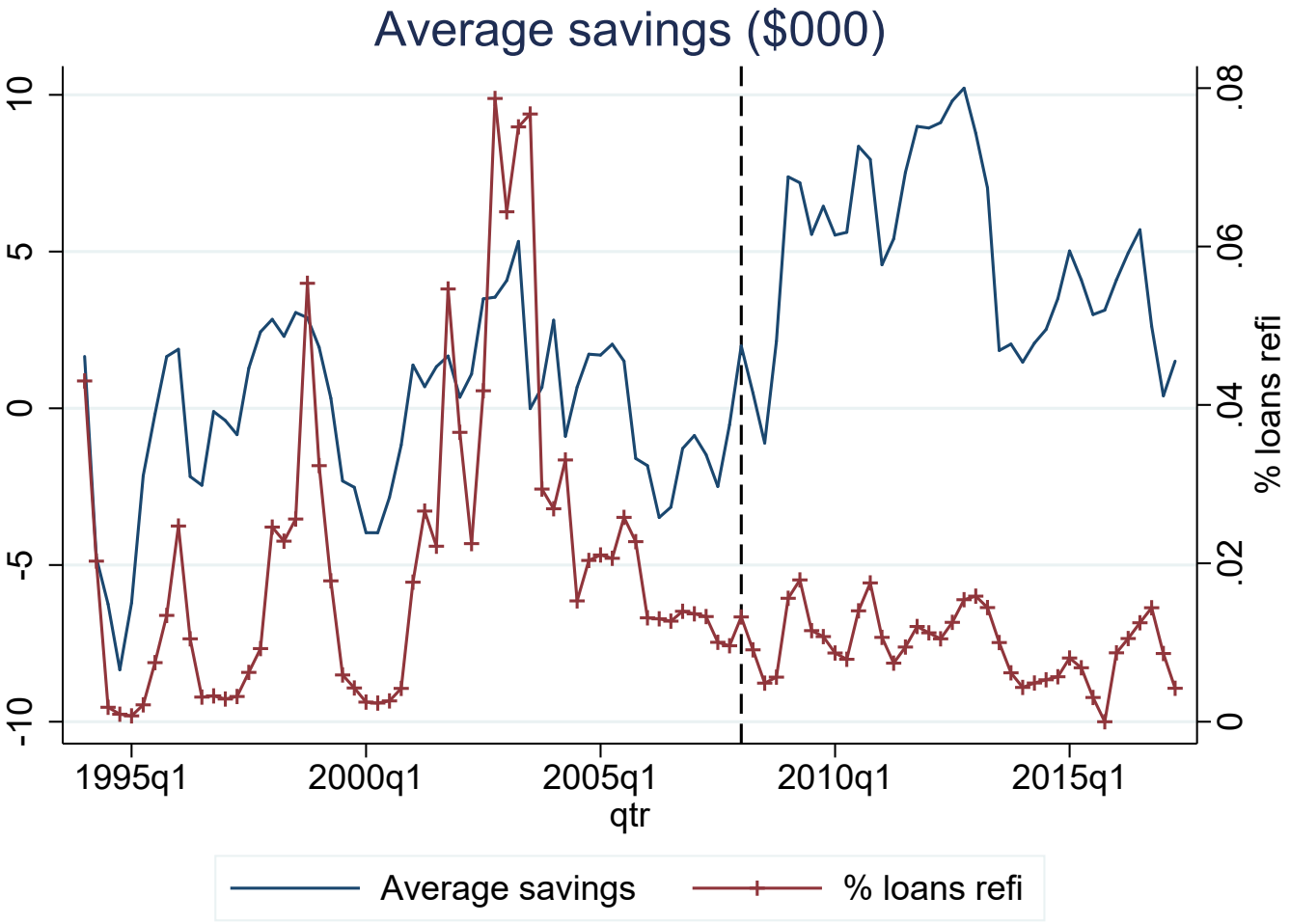
For county c in quarter t, we estimate

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

	OLS			IV using			
	Mortgage rate (I)	**Futures (II)**	**Δ2yr Treasury (III)**	**Futures (IV)**	**Δ2yr Treasury (V)**	**Futures (VI)**	**Δ2yr Treasury (VII)**
ΔR(t)	0.076***			0.330***	0.331	0.419***	0.387
	(0.024)			(0.070)	(0.173)	(0.100)	(0.239)
ΔR(t) x (i-i0-ADL)	0.021			0.209**	0.108	0.272**	0.109
	(0.021)			(0.073)	(0.119)	(0.094)	(0.126)
Ɛ(t)		0.331***	0.109				
		(0.062)	(0.070)				
Ɛ(t) x (i-i0-ADL)		0.121***	0.018				
		(0.036)	(0.054)				
SPF Controls	No	No	No	No	**No**	Yes	Yes

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More people refinance when savings are higher



Focus on the pre-2008 period.

State dependency: Additional controls

	(I)	(II)	(III)	(IV)
ΔR(t) x Average savings(t-1)	0.047***	0.044***		
ΔR(t) x Average rate gap(t-1)			0.472***	0.408***
ΔR(t) x Home equity(t-1)		0.204		0.180
ΔR(t) x Unemployment rate(t-1)		-0.015		-0.026
ΔR(t) x Median age(t-1)		-0.003*		-0.003*
ΔR(t) x Manufacturing share(t-1)		0.006*		0.008*
ΔR(t) x Share college educated(t-1)		-0.030		0.028
County Fixed Effects	Yes	Yes	Yes	Yes
County interaction controls	Yes	Yes	Yes	Yes

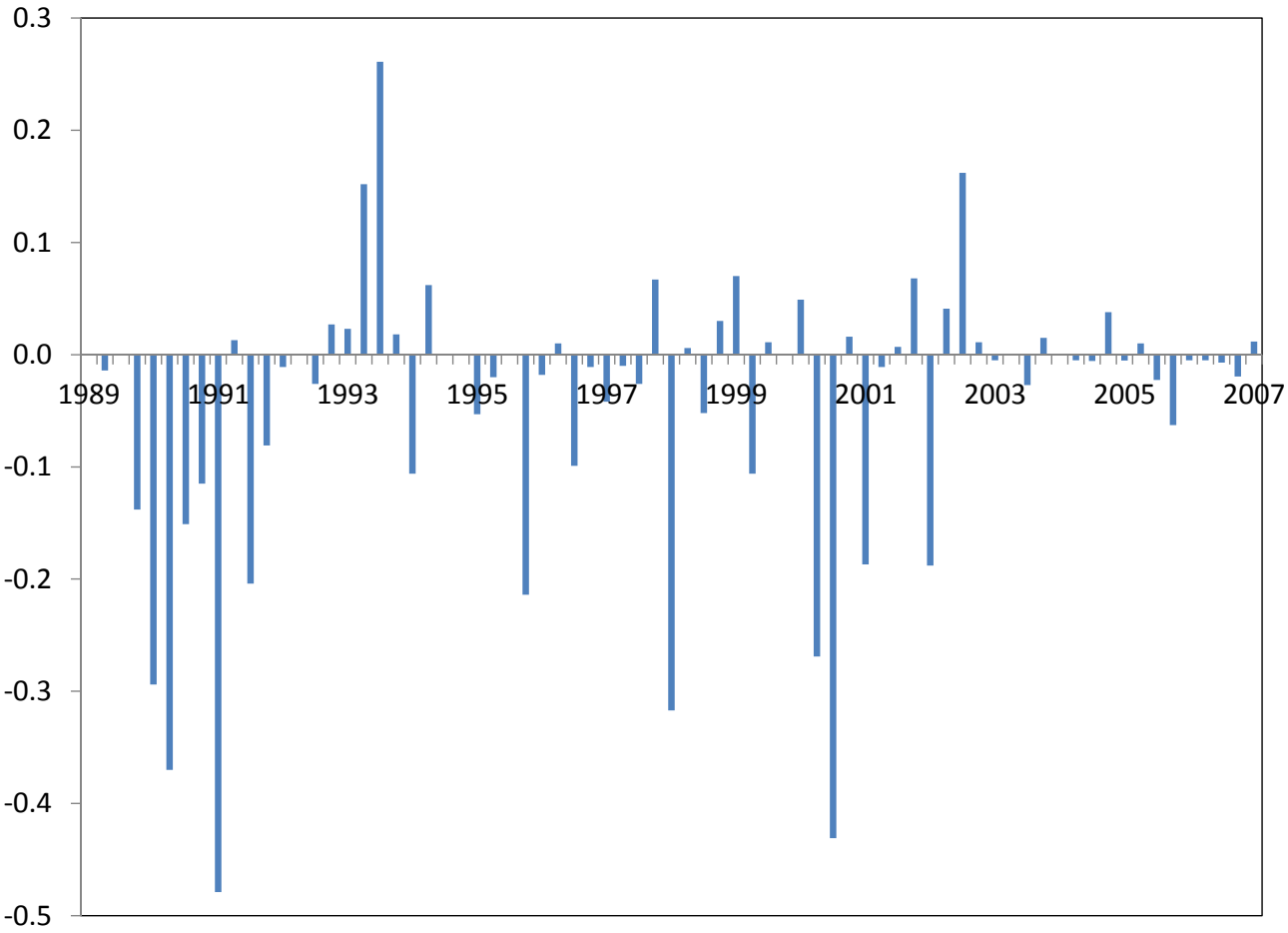
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County characteristics and average rate gaps

Time FE	Yes	Yes	No	No	No	No	No	No	No	No
County FE	Yes	No	Yes	No	No	No	No	No	No	No
R-squared	0.738	0.543	0.187	0.0546	0.0257	0.0119	0.0042	0.0004	0.0001	0.0001
Variables:	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(XIV)	(X)
Unemployment rate				0.0818***						
				(0.010)						
Per capita income					-0.3566***					
					(0.020)					
Share colleged 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 heterogeniety remains.
- Consistent with household evidence – e.g. Bhutta and Keys (2016), Anderson, Campbell, Nielsen and Ramadorai (2015). Back

Identification of monetary policy shocks



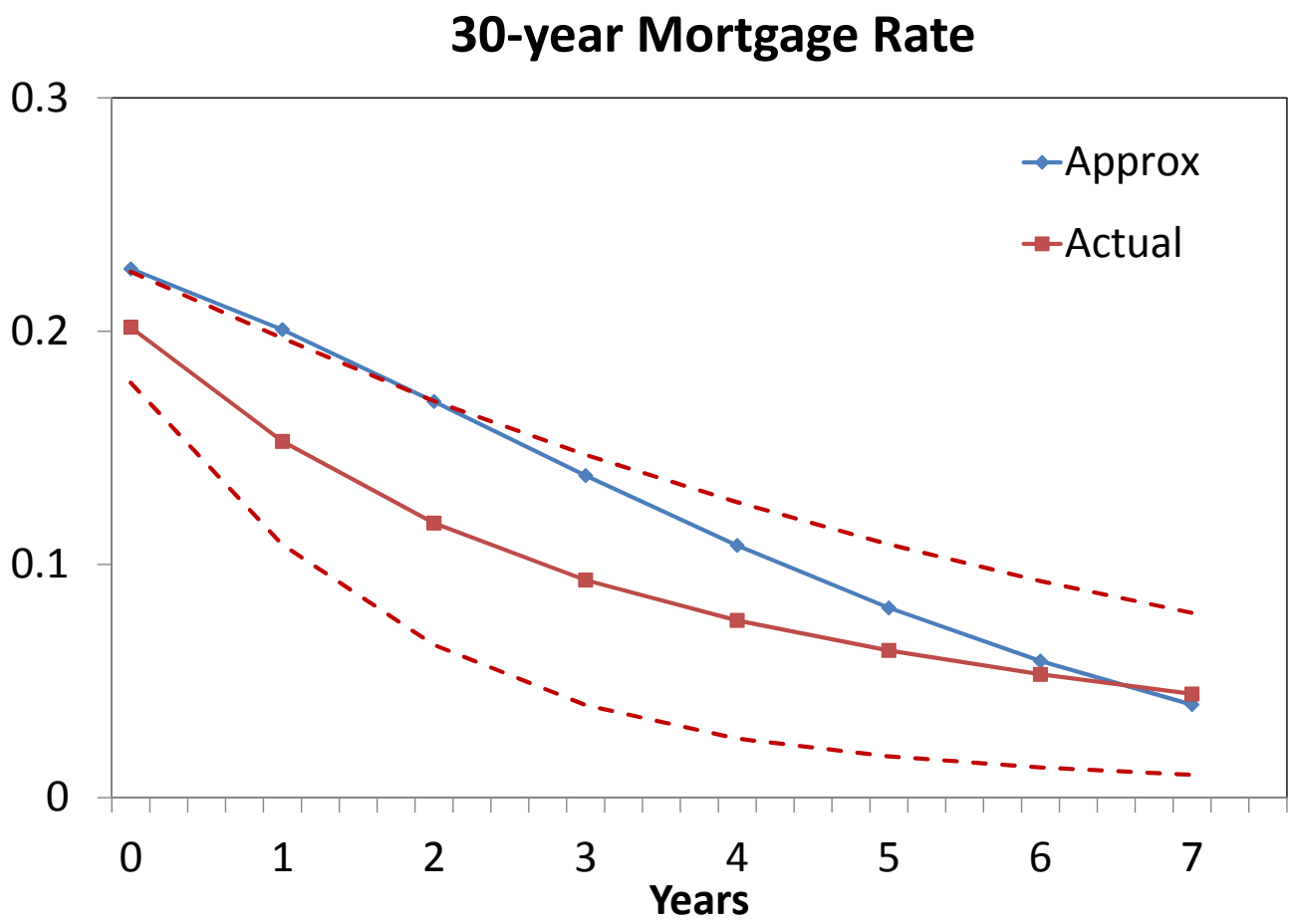
Back to FF shocks

Aggregate processes: coefficients

	Regression with dependent variable	
Variables	30-year rate$_t$	log rental rate$_t$
log y_{t-1}	-3.475	0.843
log r_{t-1}	0.334	-0.002
log p_{t-1}		-0.022
constant	-0.030	3.187

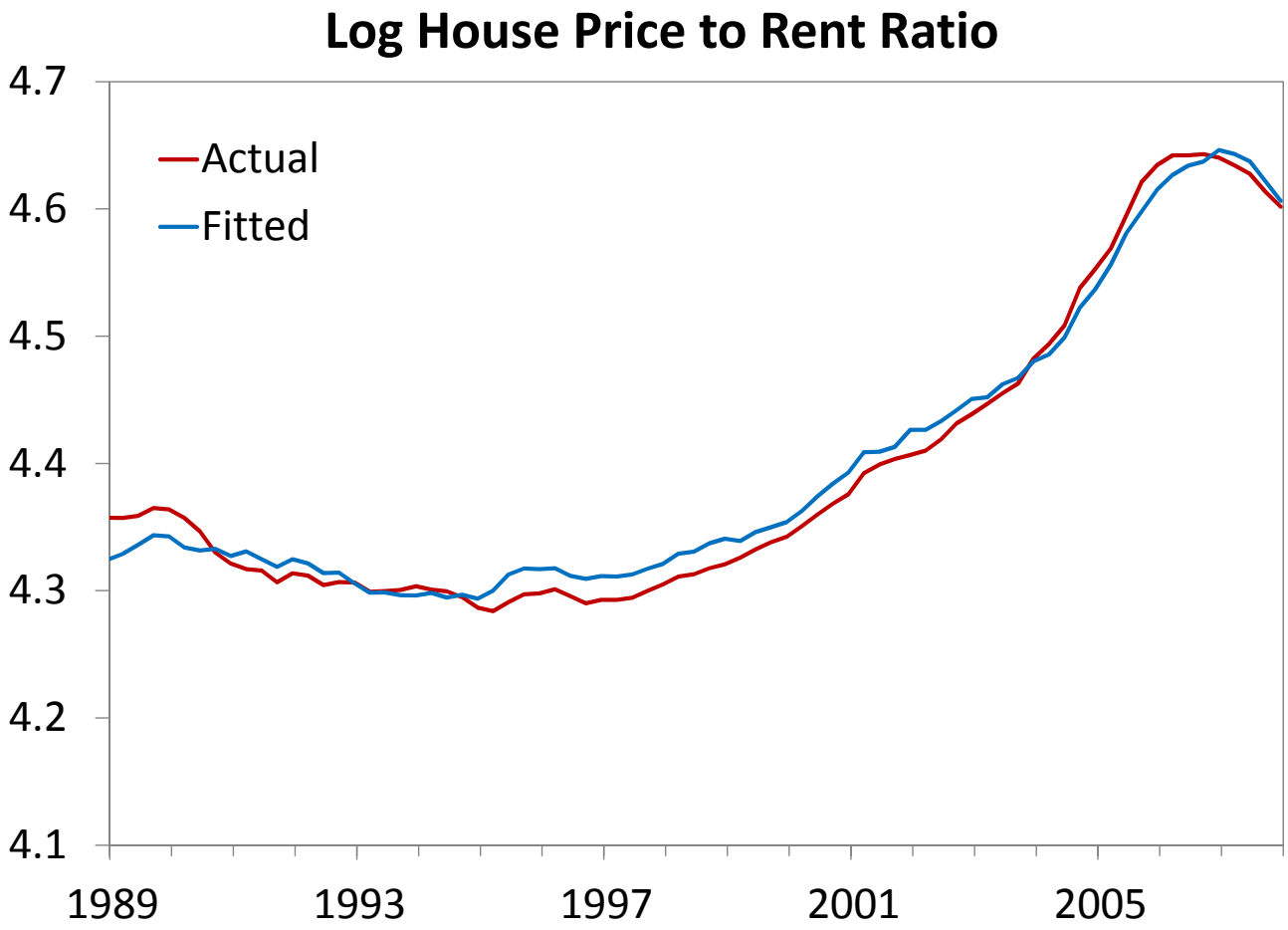
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Interest rate responses to a 1ppt monetary policy shock



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Actual and fitted log HP-to-rent ratio



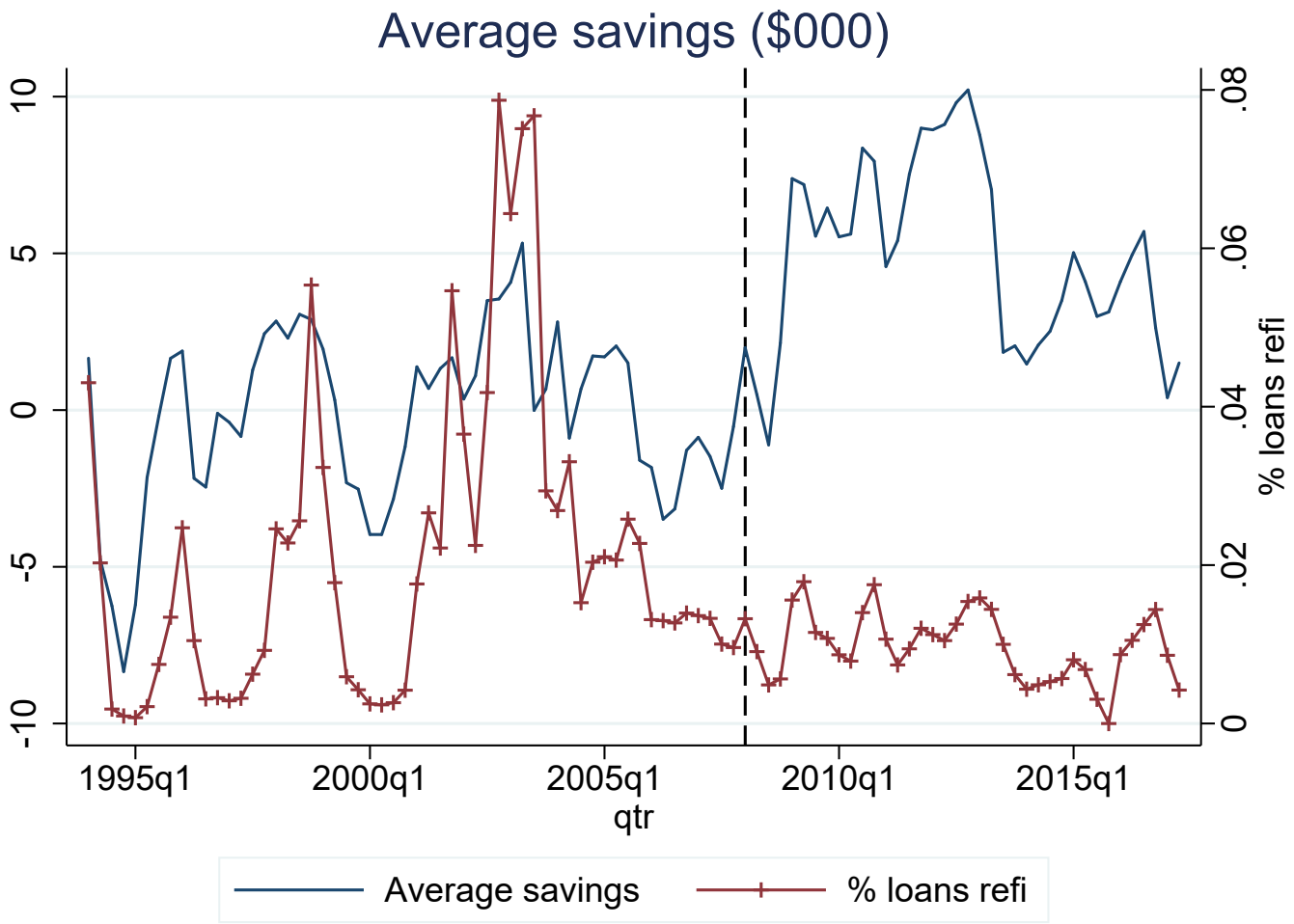
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Real mortgage rate



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Refinancing relationship breaks down post 2007



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Mortgage rates and monetary policy shocks

Fed rate cuts can affect mortgage rates and therefore potential savings

$$\triangle \text{Mortgage rate}_t = \alpha_0 + \sum_k \alpha_k \epsilon_{t-k} + \eta_t$$

	30-year	15-year	1-year	30-year	15-year	1-year
	(I)	(II)	(III)	(IV)	(V)	(VI)
	Response to futures shock			**Response to Δ 2-yr Treasury Rate**		
Current	0.599**	0.585**	0.944**	1.133***	1.111***	0.596
	(0.281)	(0.249)	(0.343)	(0.415)	(0.380)	(0.609)
After 1 year	0.753	0.739*	1.522**	0.329	0.712	1.923*
	(0.463)	(0.418)	(0.566)	(0.678)	(0.620)	(0.995)

First stage estimates: Average rate gap

First stage y-variable:	**ΔR(t)**	**ΔR(t) x average positive rate gap**	**ΔR(t)**	**ΔR(t) x average positive rate gap**
Regressed on shock type:	**Futures shock (II)**	**Futures shock (II)**	**Δ 2-yr Treasury Rate (III)**	**Δ 2-yr Treasury Rate (IV)**
Ɛ(t)	1.466***	0.385***	0.985***	0.261***
	(0.103)	(0.033)	(0.012)	(0.010)
Ɛ(t) x Average rate gap	0.048	0.487***	-0.107***	0.104***
	(0.256)	(0.095)	(0.017)	(0.014)
R-squared	0.734	0.557	0.287	0.170

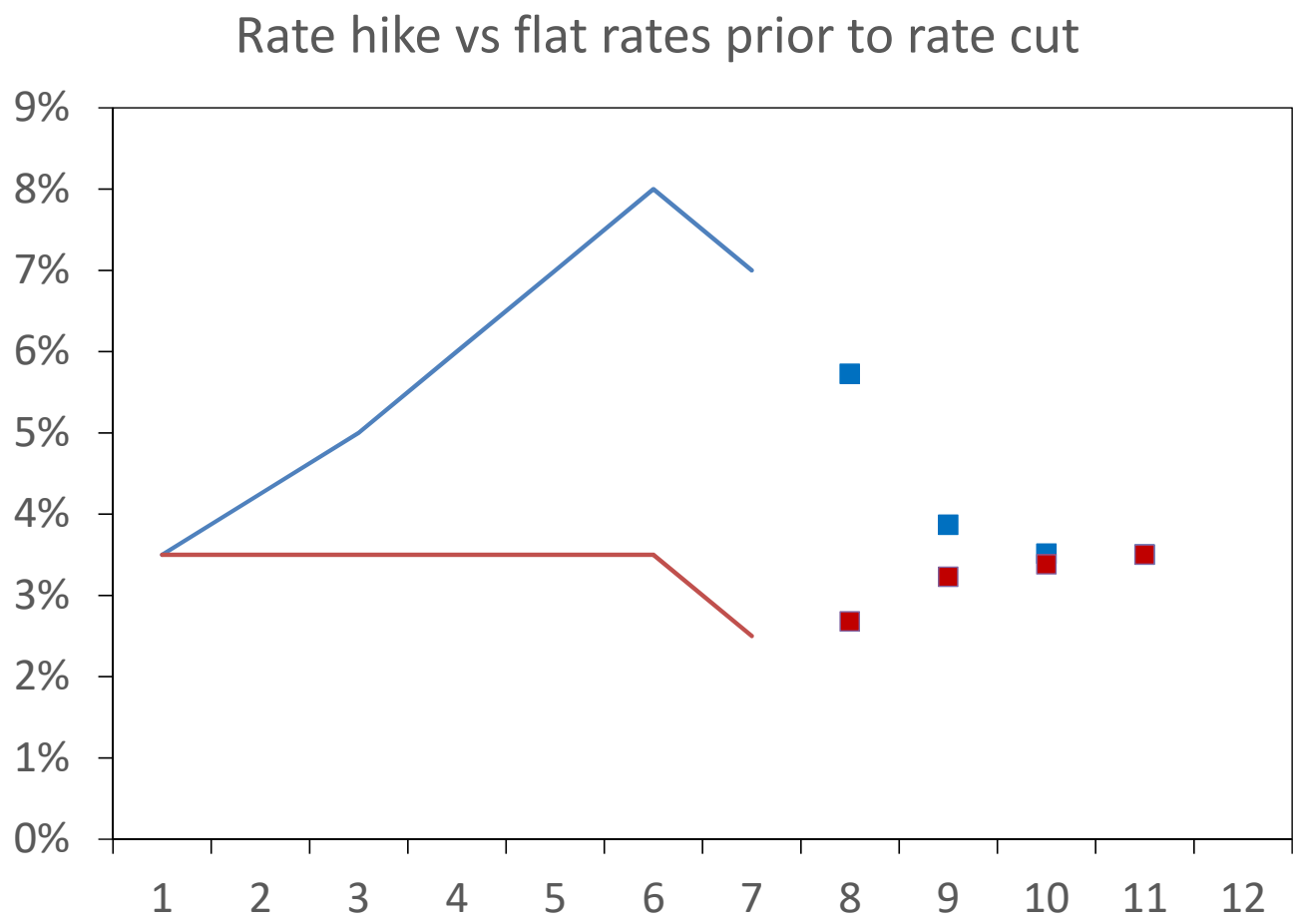
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First stage estimates: Average potential savings

First stage y-variable:	**ΔR(t)**	**ΔR(t) x Average savings**	**ΔR(t)**	**ΔR(t) x Average savings**
Regressed on shock type:	**Futures shock (II)**	**Futures shock (II)**	**Δ 2-yr Treasury Rate (III)**	**Δ 2-yr Treasury Rate (IV)**
Ɛ(t)	1.583***	1.738***	0.951***	-1.355***
	(0.113)	(0.130)	(0.011)	(0.032)
Ɛ(t) x Average savings	-0.059	0.791***	-0.024***	0.162***
	(0.049)	(0.159)	(0.003)	(0.010)
R-squared	0.293	0.156	0.288	0.177

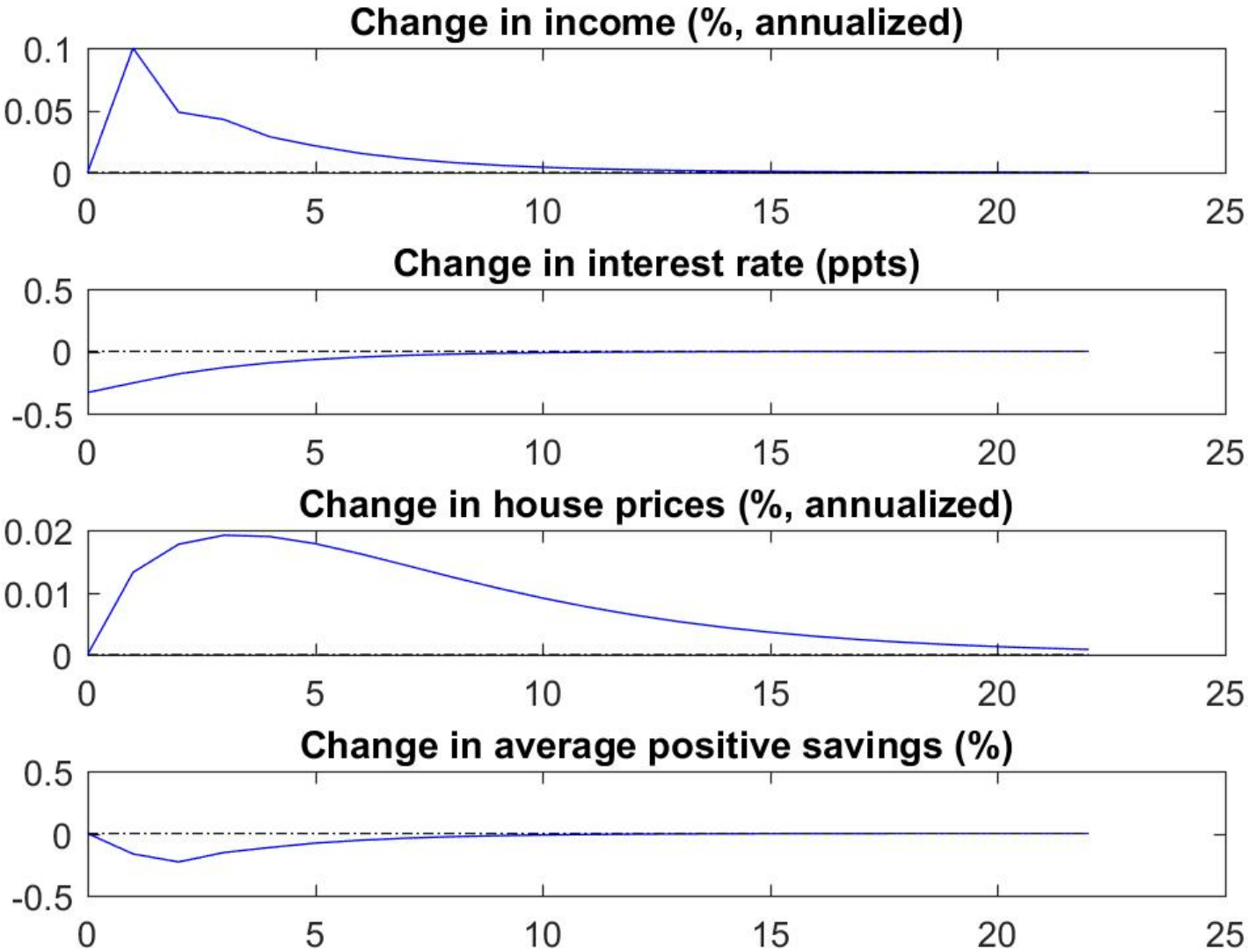
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State dependency of monetary policy



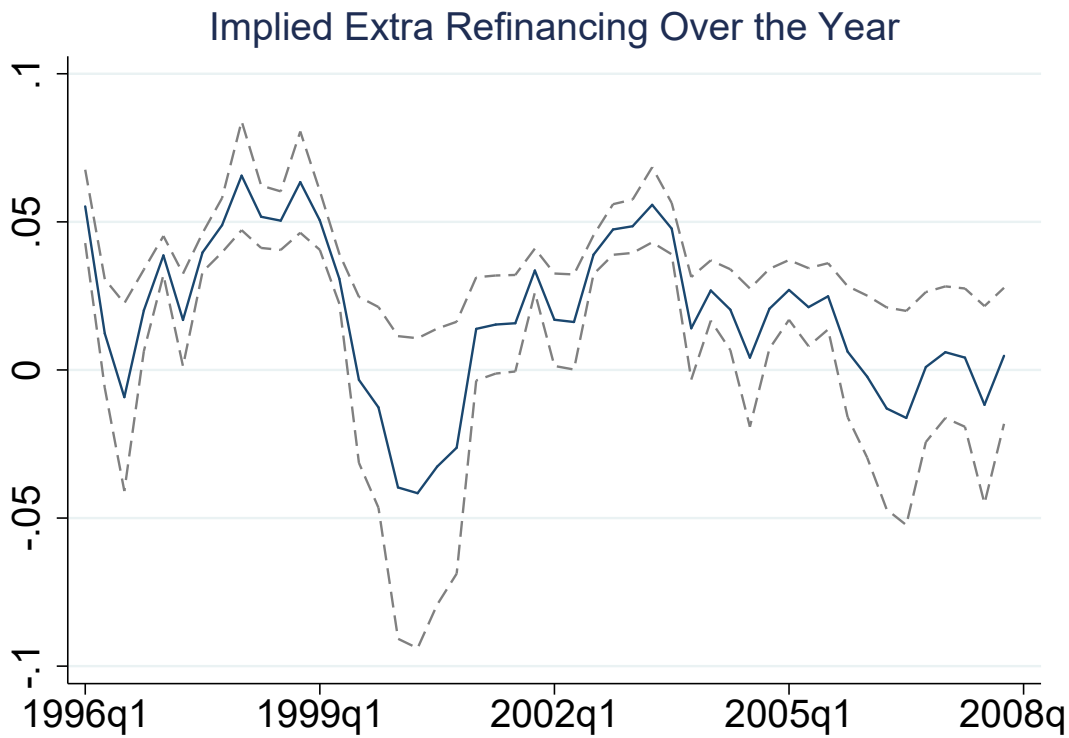
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Aggregate Variables



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Refinancing rate response to 25bps expansionary shock



$$\beta_1 \triangle R_t + \beta_2 \triangle R_t \times (\text{Average Savings})_t$$

- The implied marginal effect of a 25bp cut ($\triangle R_t$) on refinancing from column IV. Sizable effects, compared to an unconditional average rate of about 8.5%. Back

State dependency: Average rate gap

For county c in quarter t, we estimate

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

	OLS	IV using	
	Mortgage rate	Futures	Δ2yr Treasury
	(I)	(II)	(III)
ΔR(t)	0.075***	0.062***	0.195***
	(0.004)	(0.021)	(0.032)
ΔR(t) x Average rate gap	0.039**	0.389***	0.244**
	(0.014)	(0.075)	(0.101)
County Fixed Effects	Yes	Yes	Yes
SPF Controls	No	No	No
Additional county controls	No	No	No

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

- If rate gap is -14bp (mean), refinancing increases by 4ppts.
- If rate gap is 56bps (mean+1sd), refinancing increases by 8.3ppts.
- Marginal impact of a 1sd increase in rate gap is 4.3 ppts. Back

Real outcomes: building permits and average savings

For county c in quarter t, we estimate

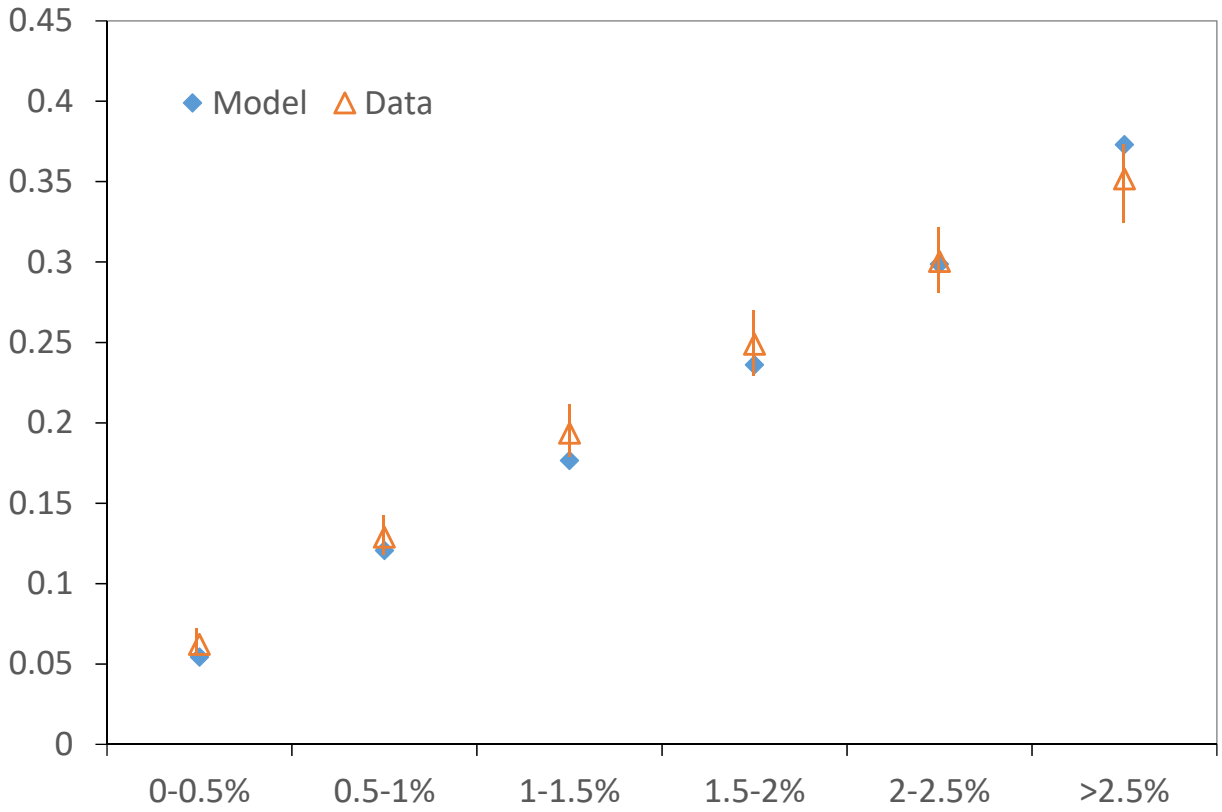
$$\Delta \log \text{Permits}_{t,t+4} = \beta_0 + \beta_1 \Delta R_t^M + \beta_2 \Delta R_t^M \times \psi_{c,t-1} + \beta_3 \psi_{c,t-1} + \eta_{ct}.$$

	OLS		IV using				
	Mortgage rate (I)	Futures (II)	Δ2yr Treasury (III)	Futures (IV)	Δ2yr Treasury (V)	Futures (VI)	Δ2yr Treasury (VII)
ΔR(t)	0.209***	0.264***	0.202***	0.290***	0.183***	0.220***	0.171***
	(0.019)	(0.044)	(0.032)	(0.049)	(0.031)	(0.070)	(0.049)
ΔR(t) x Average savings	0.012**	0.140***	0.225***	0.063**	0.070***	0.080**	0.045*
	(0.006)	(0.027)	(0.021)	(0.026)	(0.017)	(0.036)	(0.026)
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	No	Yes	Yes

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. Back

Model fit: refinancing and rate gap correlation



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Summary Statistics

	Mean	Median	Std
Mortgage balance	$123,153	$91,988	$237,103
Loan-to-valuation at origination	74%	78%	19%
FICO score	715	727	71
Interest rate	6.23%	6.00%	1.25%
Rate gap	-0.14%	-0.16%	0.70%
Potential savings	-$305	-$403	$4,727
Refinancing rate (annual)	8.50%	n.a.	n.a.

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Experiment II: Declining transaction costs

	Fixed cost	
	\$2.1K	\$1K
Effect on refinancing:		
Overall effect of a 25 bp fall in rates	1.63%	3.30%
$\beta_1 \Delta R_t$	0.15%	2.81%
$\beta_2 \Delta R_t$ times mean(φ_t)	1.48%	0.48%
Effect on consumption:		
Overall effect of a 25 bp fall in rates	1.65%	1.70%
$\beta_1 \Delta R_t$	1.17%	1.61%
$\beta_2 \Delta R_t$ times mean(φ_t)	0.48%	0.07%

Lower transaction costs lead to:

- Higher overall response to lower rates, given an initial rate gap
- Less state-dependency (marginal effects of a higher rate gap).

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Model fit: mortgage rate gap distribution (1997 vs 2000)

