Interest Rates, Debt and Intertemporal Allocation: Evidence from Notched Mortgage Contracts in the UK

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Our Question

- What is the impact of interest rates on household leverage and intertemporal consumption allocation?
  - Key question in household finance, public finance and macro
- Great Recession has renewed interest in household leverage (e.g. Hall 2011, Mian & Sufi 2014)
- Household debt $\approx$ mortgage debt
  - 89% of all household debt in the UK
  - 74% of all household debt in the US
- Yet we have little causal evidence on mortgage debt

Empirical Challenge

- Difficult to find exogenous variation in interest rates
  - **Time variation** in interest rates is endogenous
  - **Tax variation** in after-tax interest rates could be useful, but compelling quasi-experiments are rare
- We exploit quasi-experimental variation in interest rates due to notched mortgage contracts in the UK
  - Mortgage interest rate follows a step function of the loan-to-value ratio (LTV) at the time of loan origination
  - This creates notches at specific LTV thresholds

This Paper

1. **Reduced-form analysis**
   - Bunching estimates of LTV responses
   - Mortgage demand elasticities
     - Elasticity ≈ 0.3 on average, strongly heterogeneous

2. **Structural analysis**
   - Dynamic model of consumption and debt choices
   - Elasticity of Intertemporal Substitution (EIS)
     - EIS ≈ 0.1 on average, very homogeneous
   - Robustness and extensions

Institutional Setting and Data

UK Mortgage Market

- **Interest rate notches at critical LTV thresholds**
  - 60%, 70%, 75%, 80%, 85%
  - Notches vary between banks, products, and over time
- **Frequent refinancing**
  - Typical mortgage is 2-5 year fixed interest rate
  - Penalizing reset rate deters late refinancing
  - Early repayment fee and origination fee deter early refinancing
- **Our Focus: Remortgagors**
  - House value is given
  - Isolates debt choice from housing choice

Data

- **Product Sales Database** from UK Financial Conduct Authority merged with **MoneyFacts Data** (origination fees)
  - All household mortgage contracts from 2008-14
- Rich mortgage contract and household characteristics
- Our estimation sample is a **panel of remortgagors**

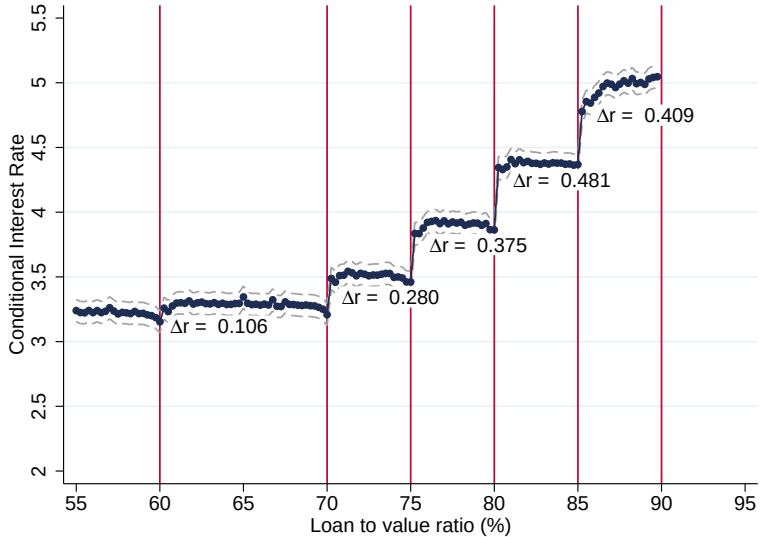
Mortgage Interest Schedule

- Interest rate jumps depend on bank, product and time
- We non-parametrically estimate interest rate jump at notches:

$$r_i = f\left(LTV_i\right) + \beta_1 \text{lender}_i + \beta_2 \text{type}_i \otimes \text{dur}_i \otimes \text{month}_i + \beta_3 \text{repayment}_i + \beta_4 \text{reason}_i + s\left(\text{term}_i\right) + \nu_i$$

- Adding borrower demographics have little impact on schedule

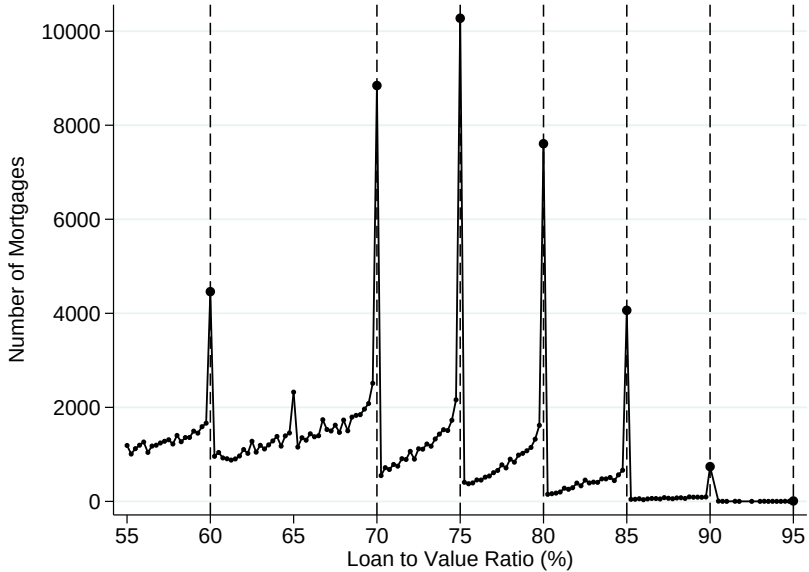
Mortgage Interest Schedule



With Individual Controls

Reduced-Form Analysis

LTV Distribution for Remortgagors



Counterfactual Distribution

Standard Approach: Fit Polynomial to Observed Distribution

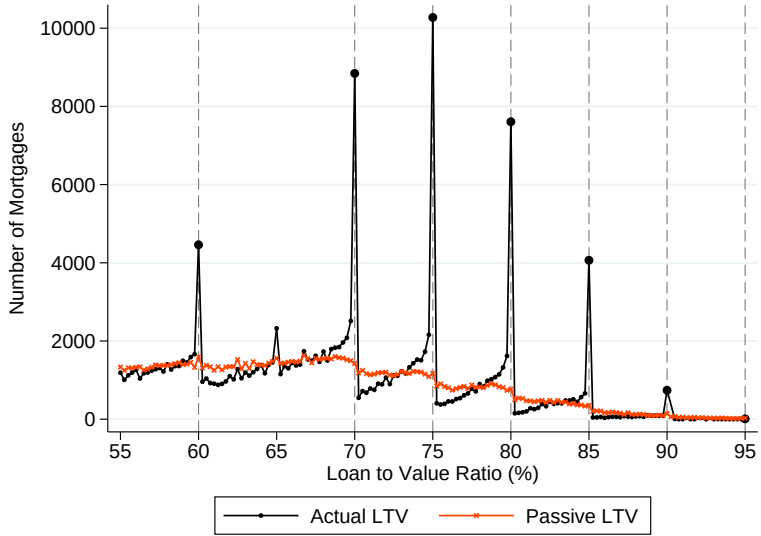
- Requires that notches only affect the distribution locally
- Here the distribution is affected globally

Our Approach: Empirical Counterfactual using Panel Data

- Previous LTV + amortization + new house price $\Rightarrow$
  Passive LTV: LTV immediately before refinancing
- **Counterfactual LTV distribution:** Passive LTV distribution + equity extraction distribution for non-bunchers

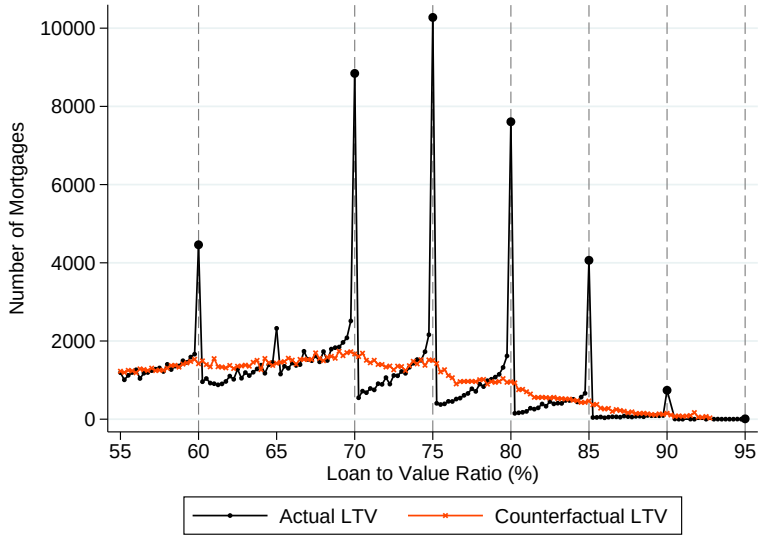
equity extraction

Actual and Passive LTV Distributions



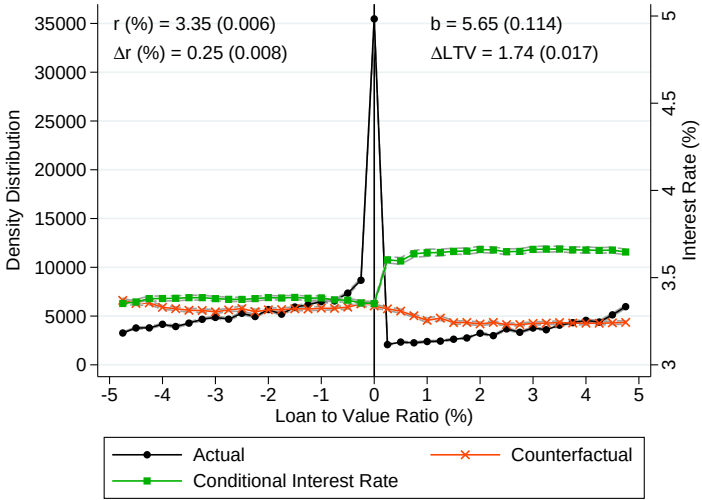
equity extraction

Actual and Counterfactual LTV Distributions



equity extraction

Bunching Estimation: Pooling Notches



Mortgage Demand Elasticities

Statistic	Notch					
	60	70	75	80	85	Pooled
Δr (%)	0.12	0.23	0.34	0.37	0.31	0.25
	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.01)
$\Delta\lambda$	0.54	1.36	2.64	3.51	5.50	1.74
	(0.03)	(0.03)	(0.05)	(0.07)	(0.26)	(0.02)
ΔEquity/V (%)	3.34	4.11	5.26	6.12	5.89	4.88
	(0.09)	(0.06)	(0.07)	(0.07)	(0.12)	(0.04)
Δc_0	1,611	3,543	5,946	7,050	9,506	4,104
	(87.72)	(83.22)	(113.97)	(145.09)	(455.76)	(39.86)
Δc_1	2,418	5,065	8,181	9,807	12,241	5,802
	(105.98)	(105.92)	(150.37)	(237.88)	(677.98)	(66.36)
r^* (%)	13.20	11.78	10.35	9.71	7.18	10.92
	(1.11)	(0.62)	(0.46)	(0.47)	(0.81)	(0.27)
Elasticity ε	0.07	0.19	0.40	0.56	1.37	0.25
	(0.01)	(0.01)	(0.02)	(0.03)	(0.26)	(0.01)

Structural Analysis

Framework

- **Baseline model**
  - T-period lifecycle model with housing choice and bequests
  - CRRA preferences over consumption
  - Perfect foresight
  - Face a notch at period 0, but not in the future
- **Robustness**
  - Uncertainty about future interest rates
  - Epstein-Zin for a broad range of risk aversion
  - Hyperbolic discounting
  - Dropping home improvers
- **In progress**
  - Moving costs
  - Facing notches in the future
  - Stochastic income and housing prices
  - Portfolio choice and liquidity constraints

Model

Preferences

$$U = \frac{\sigma}{\sigma - 1} \sum_{t=0}^{T} \delta^t \left(c_t^{\frac{\sigma-1}{\sigma}} + A H_{t+1}^{\frac{\sigma-1}{\sigma}} - \theta_t M_t \right) + \delta^{T+1} B\left(W_{T+1}\right)$$

- c_t: non-housing consumption
- H_{t+1}: housing services
- $M_t \in \{0, 1\}$: =1 when $H_{t+1} \neq (1-d)H_t$
- Assume $M_0 = 0$ (remortgagor) and $M_t = 1$ for $t > 0$ (housing chosen freely in future).
- W_t: wealth

$$W_t = P_t \left(1 - d\right) H_t - R_t D_t$$

Model

Budget constraint

$$c_t = y_t + W_t + D_{t+1} - P_t H_{t+1}$$

Budget constraint at $t = 0$

$$c_t \leq y_t + \left(\lambda_{t+1} - \bar{\lambda}_t\right) P_t \left(1 - d\right) H_t$$

where

- $\bar{\lambda}_t \equiv \frac{R_t D_t}{P_t(1-d)H_t}$ is passive LTV
- $\lambda_{t+1} \equiv \frac{D_{t+1}}{P_t(1-d)H_t}$ is chosen LTV

Baseline Model

- Remortgage decision in period zero
- **Mortgage interest notch:**
  - Gross interest rate of $R_1 = R$ if $\lambda_1 \leq \lambda^*$
  - Or $R_1 = R + \Delta R$ if $\lambda_1 > \lambda^*$
- Face a path $\{R_t\}_2^{T+1}$ anticipating not to bunch at λ^* in the future

Estimating Indifference Equation

There exists a **marginal buncher** who is indifferent between:

Interior Choice

- Interest rate $R + \Delta R$
- Unconstrained choice
- $c_1^i = (\delta (R + \Delta R))^\sigma c_0^i$
- Utility U^I

Notch Choice

- Interest rate R
- Borrow to the notch
- LTV = λ^*
- Utility U^N

$\Rightarrow$ **Indifference condition:** $U^I = U^N$

$$\Leftrightarrow F(\sigma, \Delta \ln \lambda_t, \Delta \ln R_t, X) = 0$$

Illustration

Our Approach vs Standard Approach

Standard Euler Equation Approach

$$\sigma = \frac{\Delta \ln (c_{t+1}/c_t)}{\Delta \ln R_t}$$

Our Notch Approach

$$F(\sigma, \Delta \ln \lambda_t, \Delta \ln R_t, X) = 0$$

Two key differences:

- Time variation in R_t vs notch in R_t
- LTV change $\Delta \ln \lambda_t$ vs consumption change $\Delta \ln (c_{t+1}/c_t)$

EIS Estimates

Statistic	Notch					
	60	70	75	80	85	Pooled
$\Delta\lambda$	0.54 (0.03)	1.36 (0.03)	2.64 (0.05)	3.51 (0.07)	5.50 (0.26)	1.74 (0.02)
a	0.67 (0.11)	0.17 (0.05)	0.33 (0.06)	0.14 (0.03)	0.05 (0.02)	0.36 (0.04)
$\Delta\lambda_{Adj}$	1.68 (0.45)	1.70 (0.15)	4.08 (0.38)	4.22 (0.23)	6.15 (0.34)	2.85 (0.22)
EIS σ	0.10 (0.05)	0.05 (0.01)	0.14 (0.02)	0.12 (0.01)	0.24 (0.05)	0.07 (0.01)

Parameters

Heterogeneity in EIS

Estimated From Pooled Notch

Covariate	Quartile 1	2	3	4
Age	0.05	0.06	0.10	0.09
	(0.01)	(0.02)	(0.04)	(0.03)
Income	0.09	0.08	0.05	0.07
	(0.03)	(0.02)	(0.01)	(0.04)
Loan to Income	0.05	0.06	0.06	0.10
	(0.03)	(0.02)	(0.01)	(0.03)
House Price Growth	0.07	0.05	0.04	0.24
	(0.03)	(0.01)	(0.01)	(0.06)
Interest Rate Change	0.04	0.05	0.08	0.11
	(0.01)	(0.01)	(0.02)	(0.05)

Robustness and Extensions

Panel A: Future Interest Rates $\{r_t\}_2^\infty$

	2%	$\mathbf{r_1 = 3.35\%}$	7%	15%
σ	0.0743	**0.0764**	0.0817	0.0909
	(0.0111)	(**0.0115**)	(0.0123)	(0.0138)

Panel B: Discount Factor δ

	0.7	0.9	**0.95**	0.99
σ	0.0811	0.0772	**0.0764**	0.0759
	(0.0133)	(0.0118)	(**0.0115**)	(0.0113)

Panel C: Hyperbolic Discounting β

	0.5	0.7	0.9	**1**
σ	0.0766	0.0765	0.0765	**0.0764**
	(0.0115)	(0.0115)	(0.0115)	(**0.0115**)

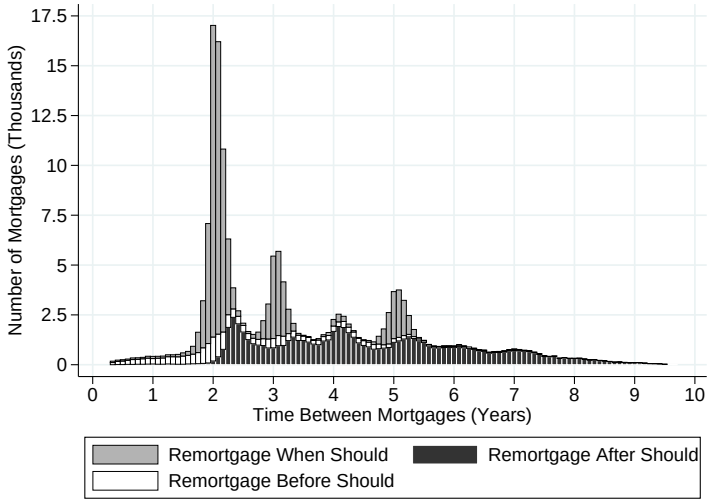
Panel D: Risk Aversion γ **(With Uncertainty)**

	0	5	10	100
σ	**0.0764**	0.0795	0.0781	0.0749
	(**0.0115**)	(0.0120)	(0.0117)	(0.0112)

Conclusions

- Novel source of quasi-experimental interest rate variation
- Elasticities of mortgage demand (reduced-form)
  - Relatively large and strongly heterogeneous elasticities
  - Important for monetary and tax policy, but not a deep parameter invariant to environment
- Elasticities of intertemporal substitution (structural)
  - Relatively small and homogeneous elasticities
  - Liquidity constraints cannot (easily) explain low elasticities
  - Important for macro and consumption theory; key statistic for monetary and fiscal policy

Households Refinance when Reset Rate Kicks In



Mortgage Interest Schedule: With Individual Controls

$$
\begin{aligned}
r_i = {} & f\left(LTV_i\right) + \beta_1 \text{lender}_i + \beta_2 \text{type}_i \otimes \text{dur}_i \otimes \text{month}_i \\
& + \beta_3 \text{repayment}_i + \beta_4 \text{reason}_i \\
& + s_1\left(\text{age}_i\right) + s_2\left(\text{income}_i\right) I\left\{\text{single}_i\right\} \\
& + s_3\left(\text{income}_i\right) I\left\{\text{couple}_i\right\} + s_4\left(\text{term}_i\right) + \nu_i
\end{aligned}
$$

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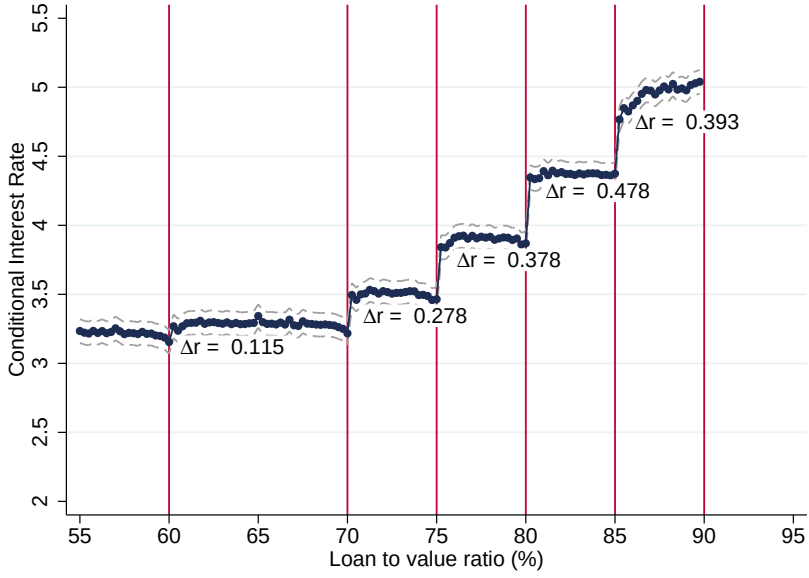
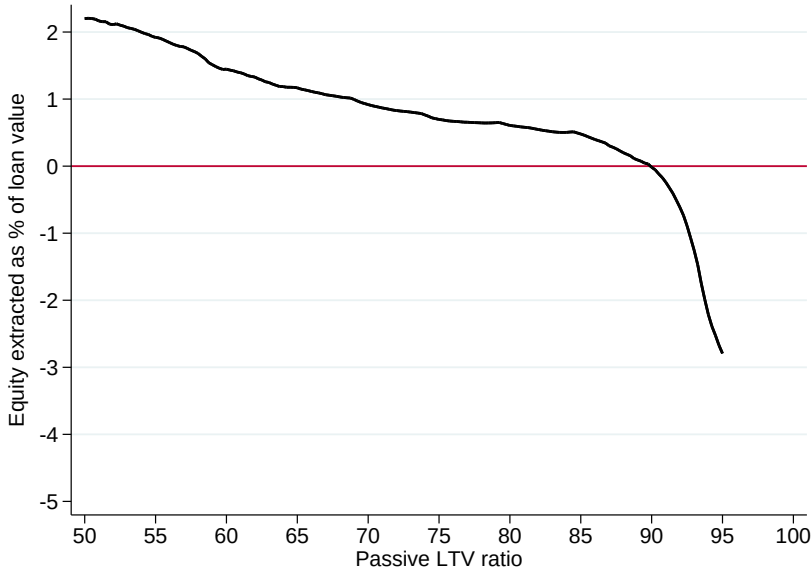
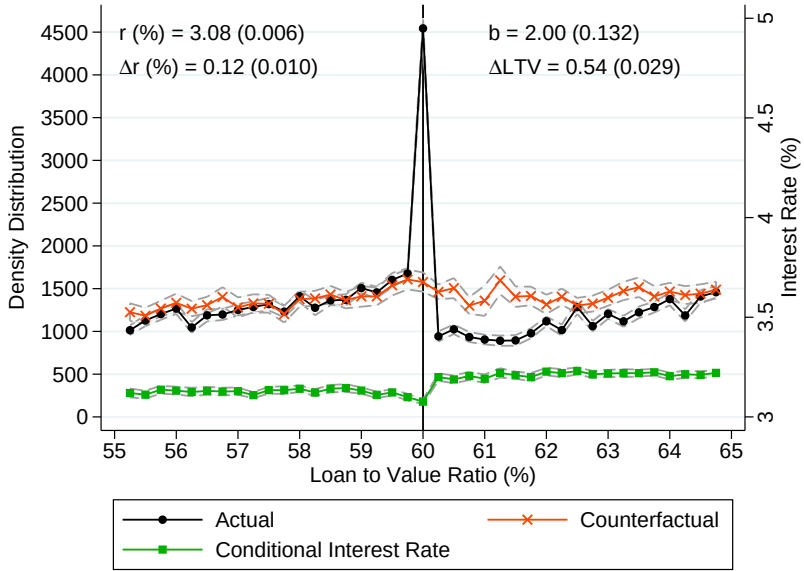
Mortgage Interest Schedule: With Individual Controls



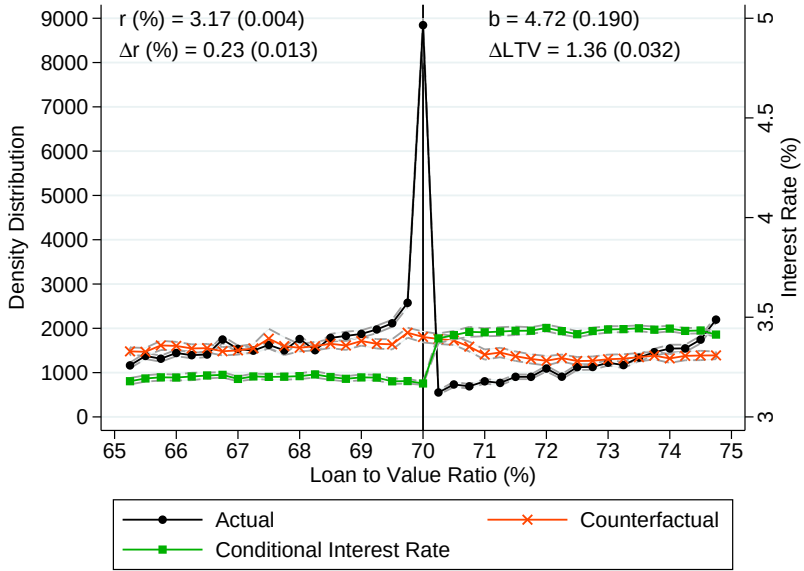
Equity Extracted by Passive LTV for Non-Bunchers



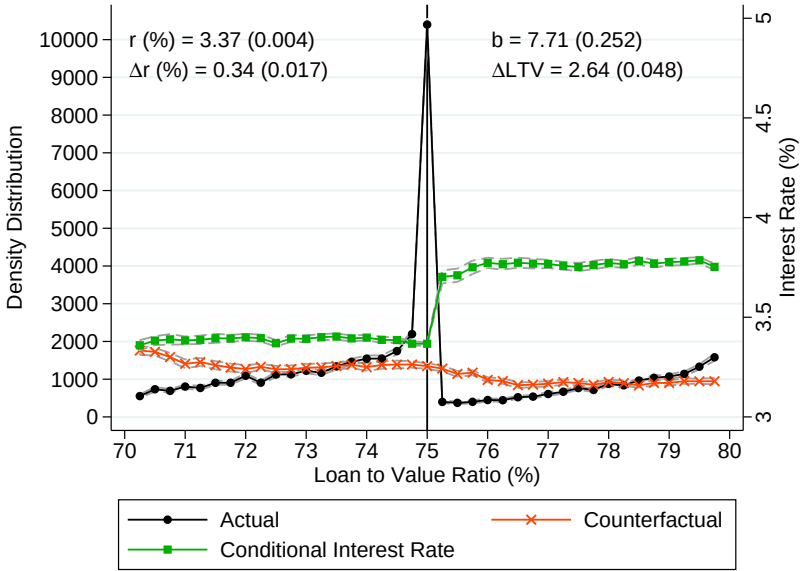
Bunching Estimation: 60% LTV Notch



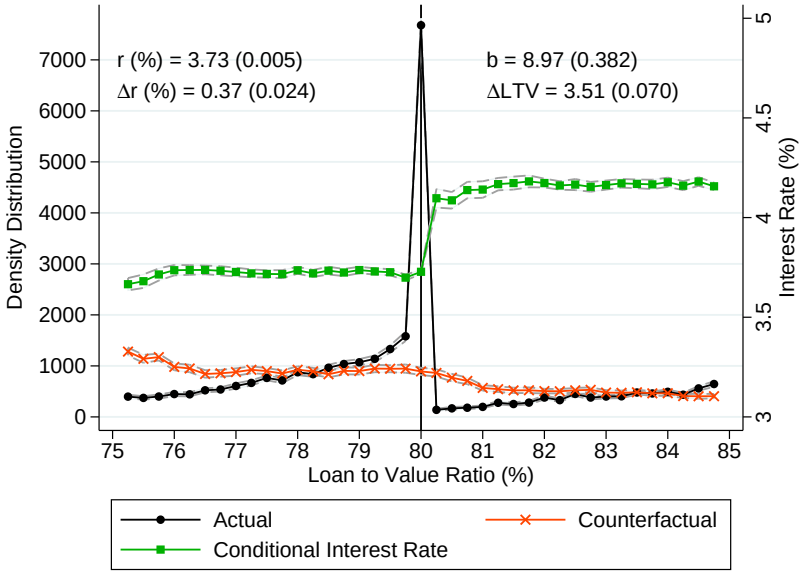
Bunching Estimation at the 70% LTV Notch



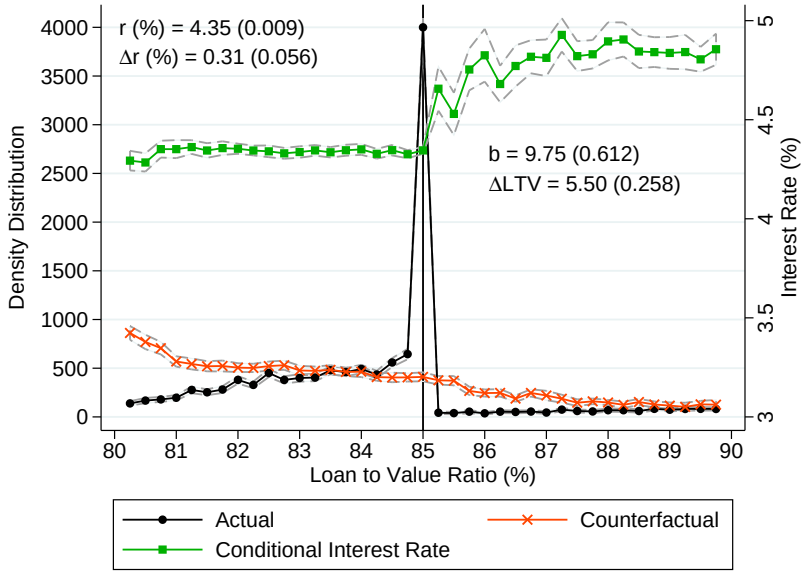
Bunching Estimation: 75% LTV Notch



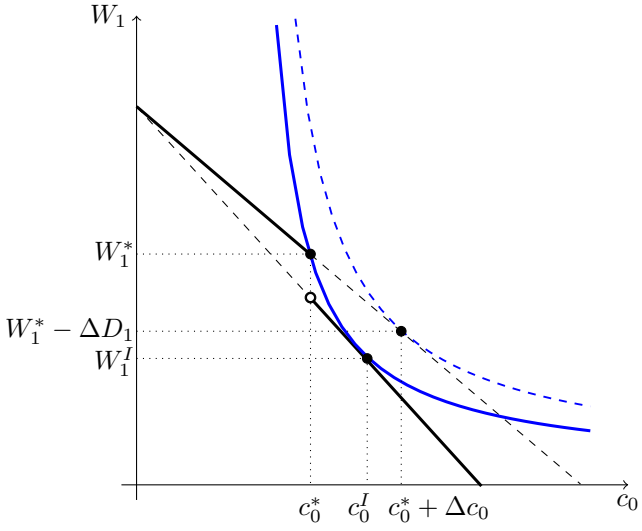
Bunching Estimation at the 80% LTV Notch



Bunching Estimation at the 85% LTV Notch



Indifference Condition: Marginal Buncher



Parameters Taken from Our Data

Parameter	Notch					
	60	70	75	80	85	60–85
Δt (yrs)	3.28 (0.02)	3.22 (0.01)	3.25 (0.01)	3.57 (0.02)	3.65 (0.03)	3.35 (0.01)
D_1^*	178,414.30 (1,263.62)	181,526.42 (992.48)	168,504.81 (838.41)	160,125.30 (916.45)	146,975.95 (963.22)	169,716.78 (454.95)
$R_0 D_0$	168,986.00 (1,300.79)	170,941.69 (983.00)	156,551.13 (774.30)	147,659.69 (828.35)	136,005.20 (896.77)	158,523.98 (449.86)
y_0	48,834.93 (532.61)	46,819.63 (393.18)	43,148.35 (239.40)	41,400.18 (224.48)	39,790.09 (247.38)	44,343.52 (150.03)
ΔEquity/V (%)	3.30 (0.09)	4.15 (0.07)	5.26 (0.07)	5.97 (0.07)	5.97 (0.10)	4.87 (0.04)
r (%)	3.09 (0.01)	3.17 (0.00)	3.38 (0.00)	3.74 (0.01)	4.37 (0.01)	3.36 (0.01)
Δr	0.12 (0.01)	0.23 (0.01)	0.33 (0.02)	0.36 (0.02)	0.34 (0.05)	0.25 (0.01)

Parameters Calibrated or Taken from Other Data

Parameter	Process	Data
P_t	$\ln P_t = 0.333 + 0.95 \ln P_{t-1} + \varepsilon_t^p$ $\varepsilon_t^p \sim N\left(0, \sigma_p^2\right)$ $\sigma_p^2 = 0.0045$	Land registry 1995-2016
Real interest rate	$rr_t = 0.21\% + 0.88 rr_{t-1} + \varepsilon_t^r$ $\varepsilon_r \tilde{} \left(0, \sigma_r^2\right)$ $\sigma_r^2 = 1.43$	Bank of England 1993-2015
Nominal interest rate	$R_t = 1 + \max\left\{2\% + rr_t, 0.5\right\} + r_{LTV}\left(LTV\right)$	
y_t	Cancels out of indifference eq.	
A	To match housing wealth to income ratio of 4.65	BoE
Bequest motivation	Median bequest of 0	HMRC
β	0.95	

Back

Optimization Frictions

- Kleven-Waseem non-parametric friction adjustment:
  - Estimate fraction of non-optimizers from **strictly dominated region** above notch $\rightarrow$ adjust bunching using this fraction
- We use a parametric friction adjustment:
  - There is no strictly dominated region here
  - But given preferences with $\delta > 0$, there exist regions of choice inconsistent with any $\sigma \geq 0$
  - Use density mass in this region to estimate the fraction a of non-optimizers

Mortgage Menu in a Large UK Bank

Maximum Loan to Valuation (LTV) of 90%

- 2 Year Fixed Standard ›
- 2 Year Fixed Fee Saver* ›
- 2 Year Fixed Premier and Advance Standard ›
- 5 Year Fixed Standard ›
- 5 Year Fixed Fee Saver* ›
- 5 Year Fixed Premier and Advance Standard ›

Maximum Loan to Valuation (LTV) of 85%

- 2 Year Fixed Standard ›
- 2 Year Fixed Fee Saver* ›
- 2 Year Fixed Premier and Advance Standard ›
- 5 Year Fixed Standard ›
- 5 Year Fixed Fee Saver* ›
- 5 Year Fixed Premier and Advance Standard ›

Maximum Loan to Valuation (LTV) of 80%

- 2 Year Fixed Standard ›
- 2 Year Fixed Fee Saver* ›
- 2 Year Fixed Premier and Advance Standard ›
- 5 Year Fixed Standard ›
- 5 Year Fixed Fee Saver* ›

Mortgage Interest Schedule in a Large UK Bank

2 Year Fixed Standard

Max loan-to-value	Initial interest rate	Initial interest rate applied until	This reverts to the Variable Rate/BTL Variable Rate, currently	Overall cost for comparison (APR)	Booking fee
90%	3.29%	2 Years Fixed until 31.07.17	3.94%	4% APR	£999
85%	2.29%	2 Years Fixed until 31.07.17	3.94%	3.8% APR	£999
80%	1.99%	2 Years Fixed until 31.07.17	3.94%	3.7% APR	£999