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

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The views expressed are those of the authors and do not necessarily reflect the views of the Bank of England, the Monetary Policy Committee, the Financial Policy Committee or the Prudential Regulatory Authority. All charts and estimates use data provided by the Financial Conduct Authority and MoneyFacts.

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. **Conceptual Framework**
   - How do **bunching moments** translate into the EIS?
   - How do bunching moments translate into the **EIS**?
   - What is the relationship between the EIS and the reduced form elasticity of borrowing to interest rates?
2. **EIS estimates: Simple Model**
   - EIS ≈ 0.1 on average, very homogeneous
3. **Full lifecycle model**
   - Addresses remaining concerns in simple model
     - Liquidity vs. consumption
     - Risk aversion vs. EIS
   - EIS ≈ 0.1 on average, very robust to assumptions

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**

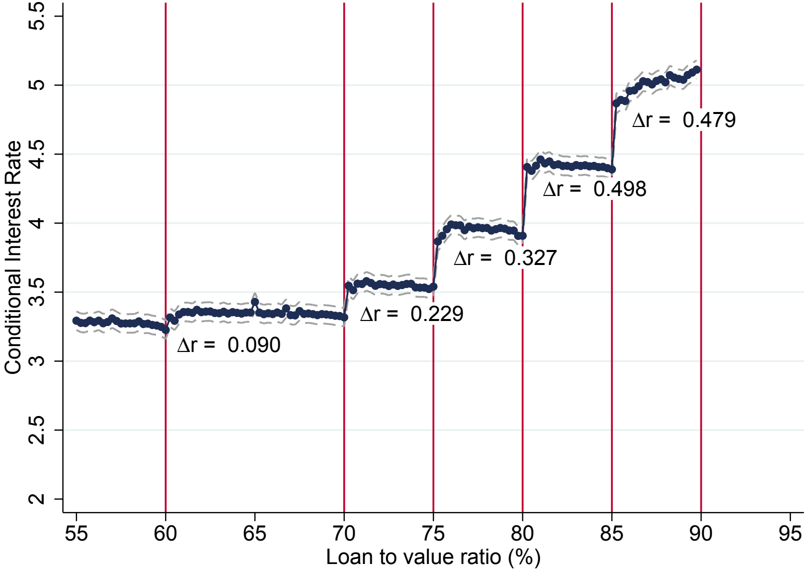
Mortgage Interest Schedule

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

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

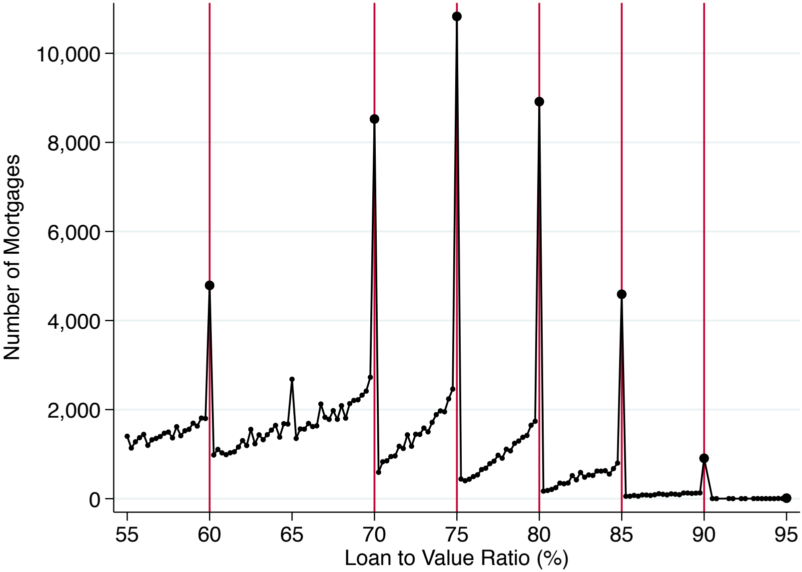
- Adding borrower demographics have little impact on schedule

Mortgage Interest Schedule



With Individual Controls

LTV Distribution for Remortgagors



Counterfactual Distribution

Standard Approach: Fit Polynomial to Observed Distribution

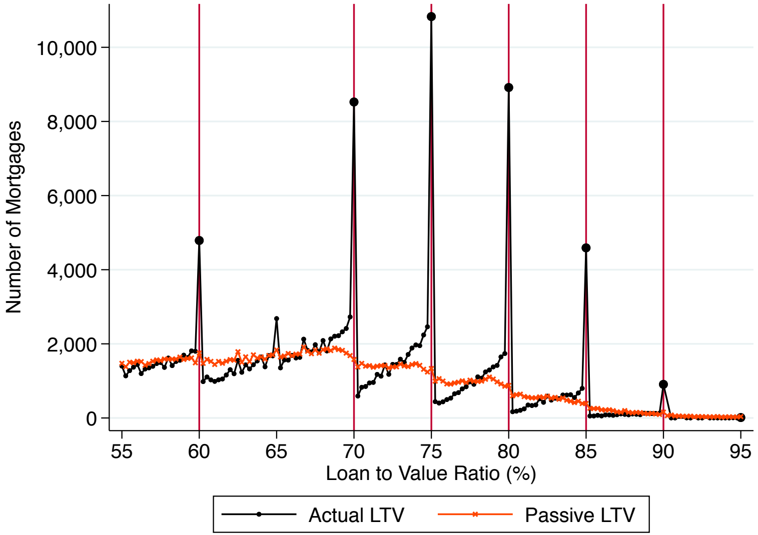
- Requires that notches only affect the distribution locally
- Here the distribution is affected globally

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

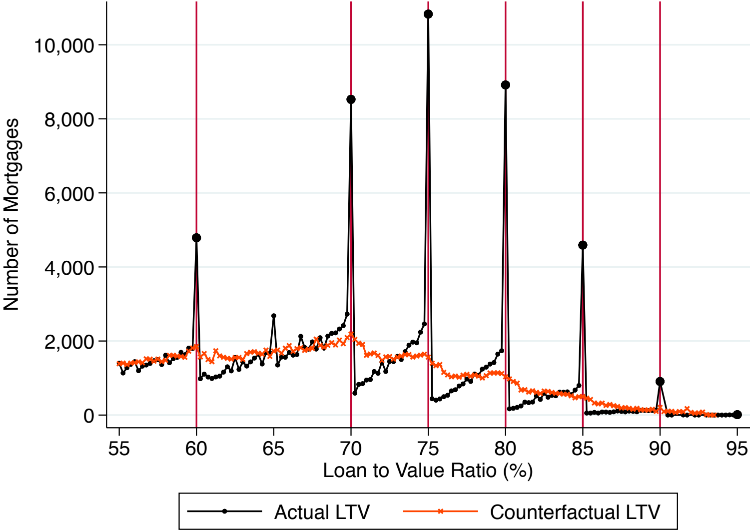
equity extraction

Actual and Passive LTV Distributions



equity extraction

Actual and Counterfactual LTV Distributions



equity extraction

Conceptual Framework

Setup

- Two periods 0 and 1, perfect foresight
- Household consumes non-durables c_t and housing H_t
- Values housing separably, does not move, and doesn't value end-of-life wealth
- Lifetime utility from consumption: $\frac{\sigma}{\sigma-1}\left(c_0^{\frac{\sigma-1}{\sigma}} + \delta c_1^{\frac{\sigma-1}{\sigma}}\right)$
- Initial wealth W_0; income y_t in period t
- No other assets, only liability is mortgage at interest rate R
  - Initially (counterfactual) R is constant

Constraints and Optimization

$$c_0 = y_0 + W_0 - (1-\lambda) P_0 H$$

$$c_1 = y_1 - R\lambda P_0 H + (1-d) P_1 H$$

FOC:

$$c_1 = (\delta R)^{\sigma} c_0$$

λ: LTV, P_t: house price, d: depreciation

$\Rightarrow \lambda$ monotonically decreasing in W_0 and R

Smooth W_0 population distribution $\Rightarrow$ smooth *counterfactual* LTV distribution $f_0(\lambda)$

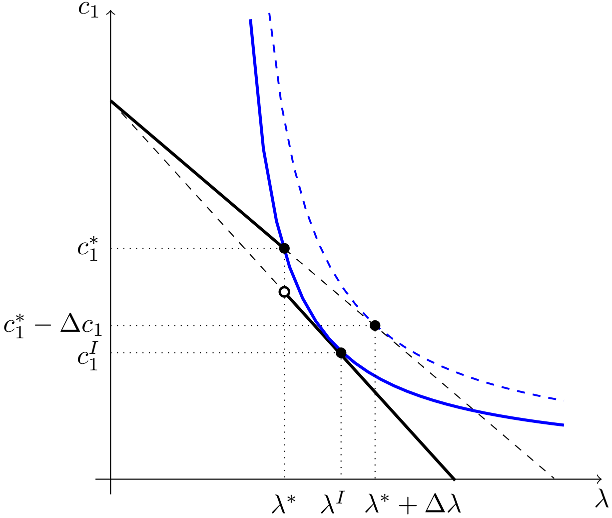
Introducing a Notch

Now let's introduce a notch at LTV λ^*

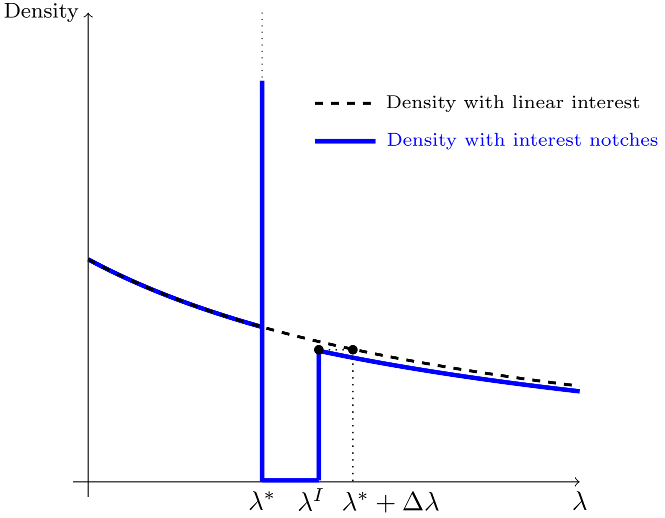
Interest rate R for $\lambda \leq \lambda^*$

Interest rate $R + \Delta R$ for $\lambda > \lambda^*$

Indifference Curves



Actual and Counterfactual LTV Distribution



Borrowing Choices

With constant rate R (counterfactual), borrows $\lambda^* + \Delta\lambda$

With notched contract, discrete choice between

- interior choice λ at interest rate $R + \Delta R$ or
- $\lambda = \lambda^*$ at interest rate R

λ^I denotes LTV where HH indifferent btw interior and bunching

The bunching moment gives

$$B = \int_{\lambda^*}^{\lambda^* + \Delta\lambda} f_0(\lambda)\, d\lambda \simeq f_0(\lambda^*)\, \Delta\lambda$$

Borrowers' Utility

Value of interior choice λ_I at rate $R + \Delta R$:

$$V^I(\sigma, \delta, \Delta\lambda, \Delta R, \mathbf{x}) = \frac{\sigma}{\sigma - 1} \left(P_0 H\right)^{\frac{\sigma-1}{\sigma}} \frac{\left(\delta^\sigma \left(R + \Delta R\right)^{\sigma-1} + 1\right)^{\frac{1}{\sigma}}}{\left(\delta R\right)^{\sigma-1}} \times$$

$$\left(\left(\frac{(\delta R)^\sigma}{R + \Delta R} + 1\right)\left(\frac{y_1}{P_0 H} + \Pi_1\right) - \left(\left(\delta R\right)^\sigma + R\right)\left(\lambda^* + \Delta\lambda\right)\right)^{\frac{\sigma-1}{\sigma}}$$

Value of bunching at λ_* at rate R:

$$V^N(\sigma, \delta, \Delta\lambda, \mathbf{x}) = \frac{\sigma}{\sigma - 1} \left(P_0 H\right)^{\frac{\sigma-1}{\sigma}} \times$$

$$\left(\begin{array}{c} \frac{1}{(\delta R)^\sigma} \left(\frac{y_1}{P_0 H} + \Pi_1 - R\lambda^* - \left(\left(\delta R\right)^\sigma + R\right)\Delta\lambda\right)^{\frac{\sigma-1}{\sigma}} \\ +\delta \left(\frac{y_1}{P_0 H} + \Pi_1 - R\lambda^*\right)^{\frac{\sigma-1}{\sigma}} \end{array} \right)$$

Indifference Equation

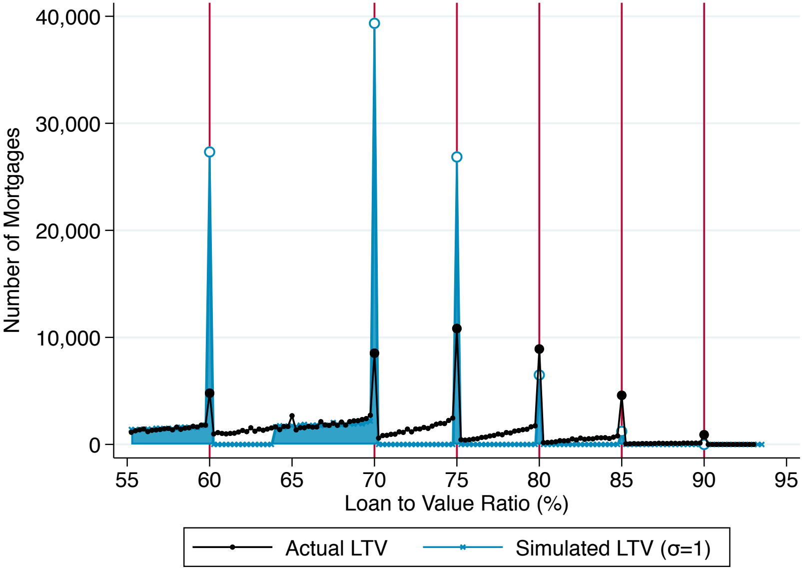
Proposition

Given a bunching moment $\{\Delta\lambda, \Delta R\}$ and a discount factor δ, the EIS σ is the solution to the indifference equation

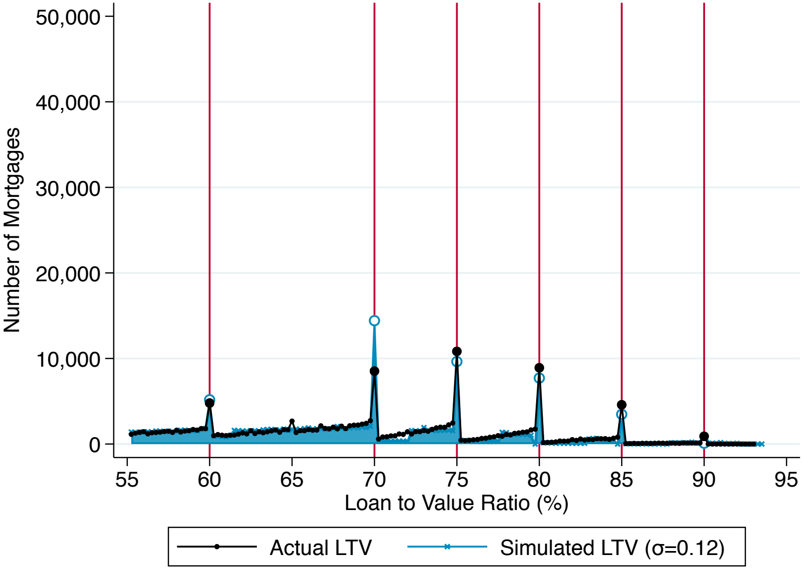
$$F\left(\sigma, \delta, \Delta\lambda, \Delta R, \mathbf{x}\right) \equiv V^{N}\left(\sigma, \delta, \Delta\lambda, \mathbf{x}\right) - V^{I}\left(\sigma, \delta, \Delta\lambda, \Delta R, \mathbf{x}\right) = 0,$$

where $\mathbf{x} = \left\{R, \lambda^{*}, \frac{y_1}{P_0 H} + \Pi_1\right\}$.

Why the EIS Can't Be 1

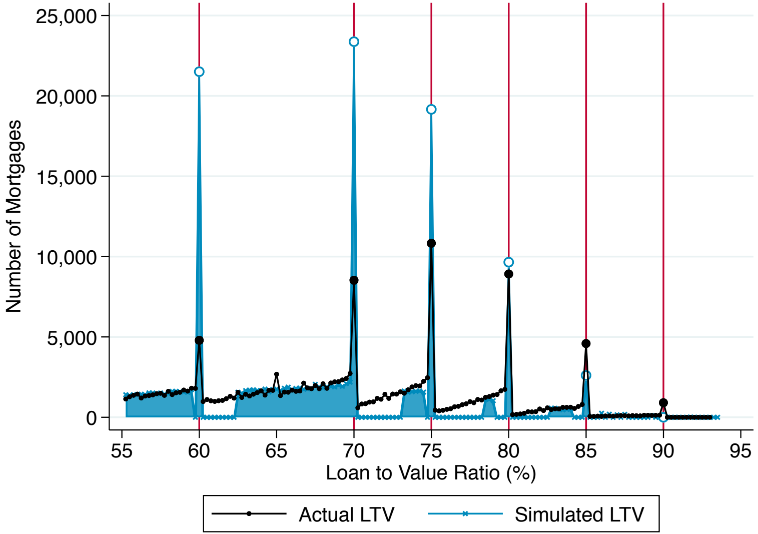


Why the EIS Has to be **Small**



Why the **EIS** Has to be Small

- $\sigma = 1$; all other parameters selected to best fit the data.



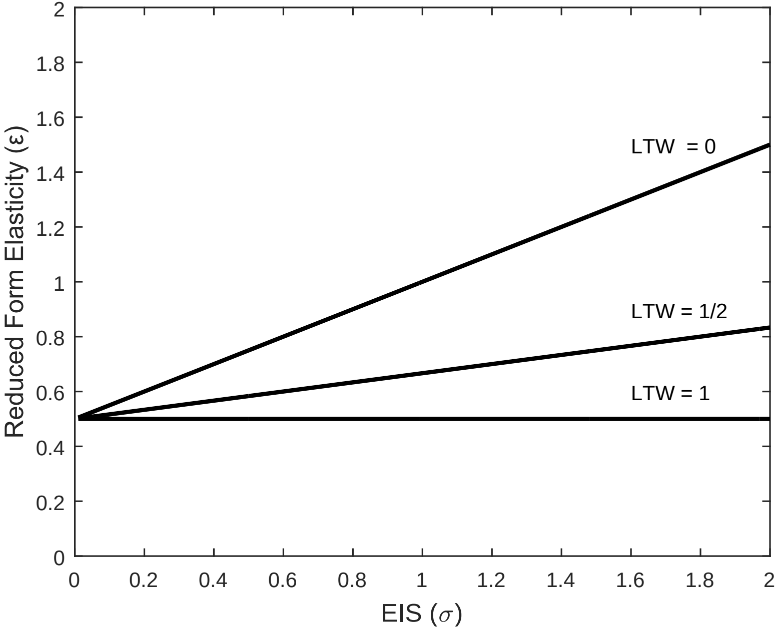
Reduced Form and Structural Elasticities

Proposition

Given the EIS σ, the discount factor δ, the gross interest rate R, and the ratio $LTW \equiv \frac{P_0 H - W_0 - y_0}{y_1 + (1-d) P_1 H}$, the elasticity of borrowing with respect to the interest rate is given by

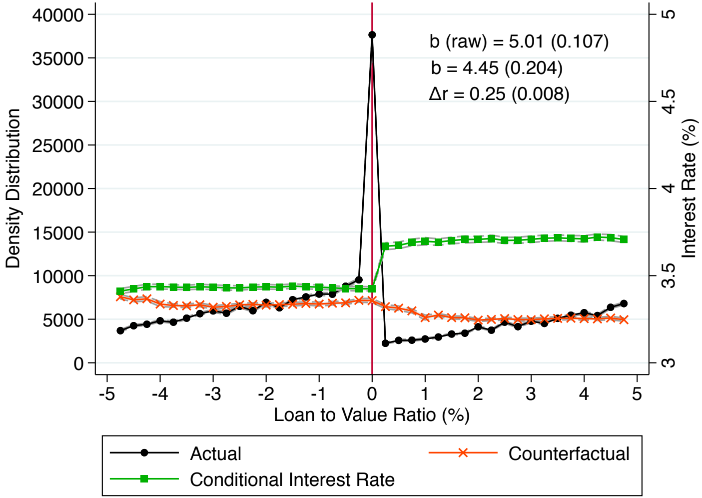
$$\varepsilon = -\frac{\partial \log \lambda}{\partial \log R} = \frac{\sigma (\delta R)^{\sigma} + R}{(\delta R)^{\sigma} + R} - \frac{\sigma (\delta R)^{\sigma} \times LTW}{1 + (\delta R)^{\sigma} \times LTW}.$$

Reduced Form and Structural Elasticities



Empirical Estimates

Bunching Estimation: Pooling Notches



Individual Notches

EIS Estimates

Statistic	Notch 60	70	75	80	85	Pooled
Panel A: Bunching Evidence						
$r(\%)$	3.17	3.25	3.44	3.76	4.38	3.42
	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
$\Delta r(\%)$	0.10	0.21	0.33	0.37	0.39	0.25
	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.01)
b	0.96	2.94	6.86	6.42	7.45	4.45
	(0.17)	(0.26)	(0.39)	(0.74)	(0.99)	(0.20)
a	0.58	0.21	0.30	0.15	0.08	0.29
	(0.05)	(0.02)	(0.03)	(0.02)	(0.03)	(0.01)
b_{Adj}	2.31	3.73	9.87	7.59	8.11	6.30
	(0.49)	(0.35)	(0.60)	(0.89)	(1.16)	(0.30)
$\Delta\lambda_{Adj}$	0.67	1.06	3.32	2.68	3.71	1.93
	(0.14)	(0.09)	(0.18)	(0.32)	(0.70)	(0.09)
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)
Panel B: Elasticities						
EIS σ	0.03	0.03	0.17	0.08	0.13	0.07
	(0.01)	(0.00)	(0.02)	(0.02)	(0.05)	(0.01)
Reduced-form ε	0.53	0.53	0.60	0.56	0.58	0.55
	(0.01)	(0.00)	(0.01)	(0.01)	(0.02)	(0.00)

Little Heterogeneity in the EIS

Covariate	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Age	0.05 (0.01)	0.09 (0.02)	0.10 (0.02)	0.15 (0.08)
Household Income	0.09 (0.02)	0.08 (0.01)	0.07 (0.01)	0.05 (0.01)
Loan to Income	0.02 (0.01)	0.05 (0.01)	0.08 (0.01)	0.07 (0.02)
Income Growth	0.05 (0.01)	0.06 (0.02)	0.07 (0.01)	0.07 (0.02)
House Price Growth Rate	0.06 (0.02)	0.05 (0.01)	0.04 (0.01)	0.13 (0.03)
Interest Rate Change (Passive)	0.02 (0.01)	0.06 (0.02)	0.11 (0.03)	0.11 (0.03)

Comments

- Other parameters matter little because they affect both sides of the indifference equation similarly.
  - Put differently, they affect the **level** of borrowing, not its **response** to borrowing.
- 2 period model crude, but curvature of the value function in richer models also largely determined by EIS $\Rightarrow$ similar indifference equation.
- Most important simplification is lack of portfolio choice
  - Observe borrowing for debt consolidation–not driven by this.
  - Buying other assets not profitable–bunching has a risk free return of 10%
  - Liquid assets would mean that our estimates are a *lower* bound

Full Lifecycle Model

Main Features

- T-period lifecycle model with housing choice and bequests
- Epstein-Zin preferences
  - Robust to wide range of risk aversion
  - Robust to hyperbolic discounting
- Liquid assets
- Variable interest rates + full notched interest rate schedule
- Income risk
- Housing choice, moving and refinancing costs

Details

Results from Lifecycle Model

Statistic	Notch 60	70	75	80	85	Average
b	0.96	2.94	6.86	6.42	7.45	4.11
	(0.17)	(0.26)	(0.39)	(0.74)	(0.99)	(0.19)
a	0.58	0.21	0.30	0.15	0.08	0.31
	(0.05)	(0.02)	(0.03)	(0.02)	(0.03)	(0.01)
b_{Adj}	2.31	3.73	9.87	7.59	8.11	5.57
	(0.49)	(0.35)	(0.60)	(0.89)	(1.16)	(0.26)
$\Delta\lambda_{Adj}$	0.67	1.06	3.32	2.68	3.71	1.88
	(0.14)	(0.09)	(0.18)	(0.32)	(0.70)	(0.09)
EIS σ	0.05	0.04	0.11	0.11	0.28	0.08
	(0.01)	(0.01)	(0.01)	(0.02)	(0.15)	(0.01)

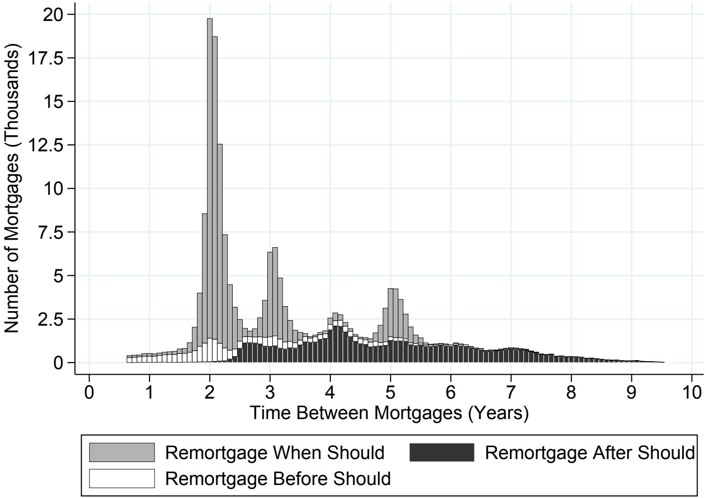
Robustness

(1)	Discount Factor δ		0.7	0.9	**0.96**	0.99
			0.13 (0.015)	0.12 (0.015)	**0.08** (**0.011**)	0.12 (0.013)
(2)	Present Bias Factor β		0.3	0.5	0.7	**1**
			0.17 (0.026)	0.14 (0.019)	0.11 (0.015)	**0.08** (**0.011**)
(3)	Risk Aversion γ		0	1	**2**	CRRA
			0.11 (0.011)	0.12 (0.012)	**0.08** (**0.011**)	0.15 (0.013)
(4)	Future Interest Rates		**+0pp**	+1pp	+2pp	+3pp
			0.08 (**0.011**)	0.11 (0.014)	0.12 (0.013)	0.12 (0.013)
(5)	House Price Trend		-0.6%	0	**0.6%**	6%
			0.10 (0.014)	0.10 (0.014)	**0.08** (**0.011**)	0.10 (0.014)
(6)	House Price Variance		0	0.004	**0.006**	0.008
			0.08 (0.009)	0.10 (0.011)	**0.08** (**0.011**)	0.16 (0.012)
(7)	Lifecycle Income Profile	Peak Slope	£44K 0%	**£46K 0.7%**	£56K 2.7%	£80K 6.5%
			0.12 (0.016)	**0.08** (**0.011**)	0.09 (0.008)	0.08 (0.016)
(8)	Unemployment Probability		3%	**5%**	7%	10%
			0.09 (0.014)	**0.08** (**0.011**)	0.11 (0.013)	0.12 (0.015)
(9)	Replacement Rate		**60%**	80%	100%	
			0.08 (**0.011**)	0.13 (0.013)	0.12 (0.016)	

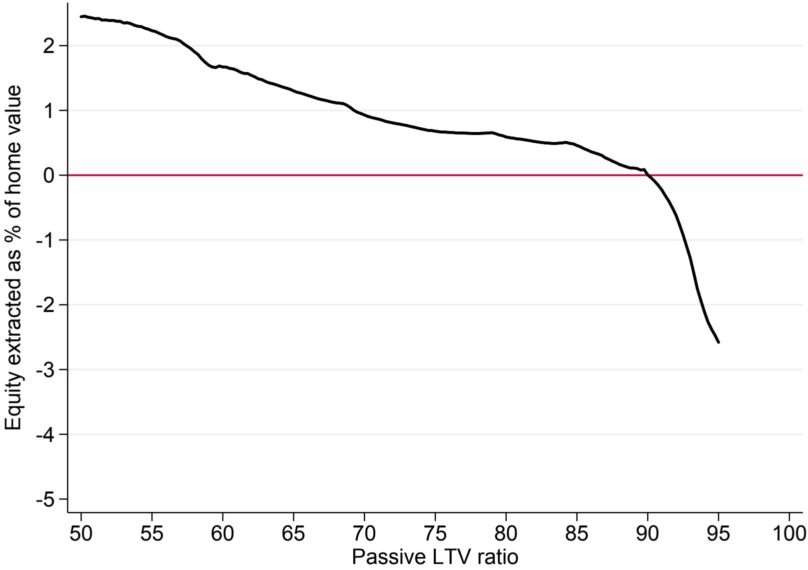
Conclusions

- Novel source of quasi-experimental interest rate variation
- Develop methodology to map bunching moments into EIS
- And to map reduced form borrowing elasticities into the EIS
- Relatively small and homogeneous values of EIS
- 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



Equity Extracted by Passive LTV for Non-Bunchers



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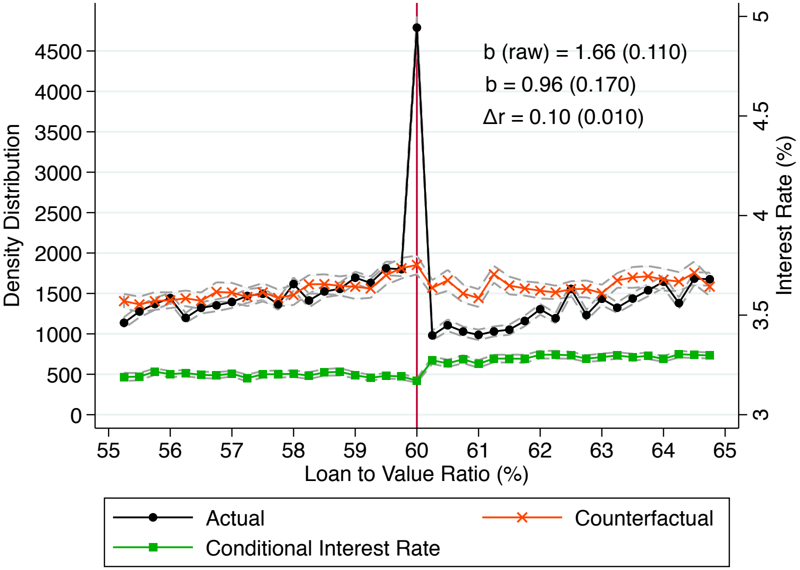
Bunching Estimation: 60% LTV Notch



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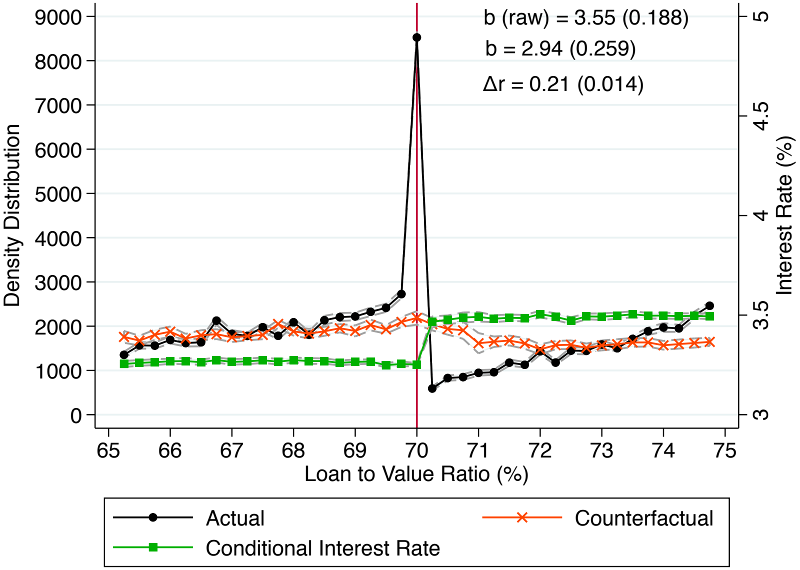
Bunching Estimation at the 70% LTV Notch



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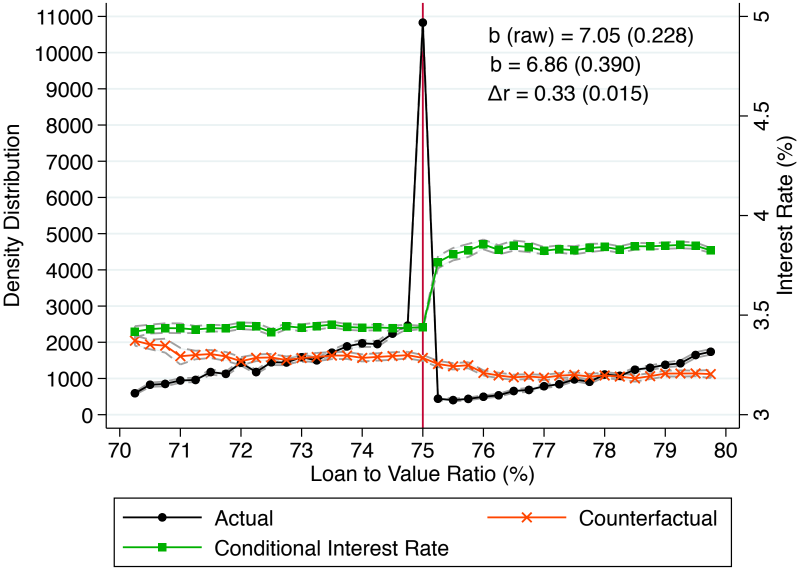
Bunching Estimation: 75% LTV Notch



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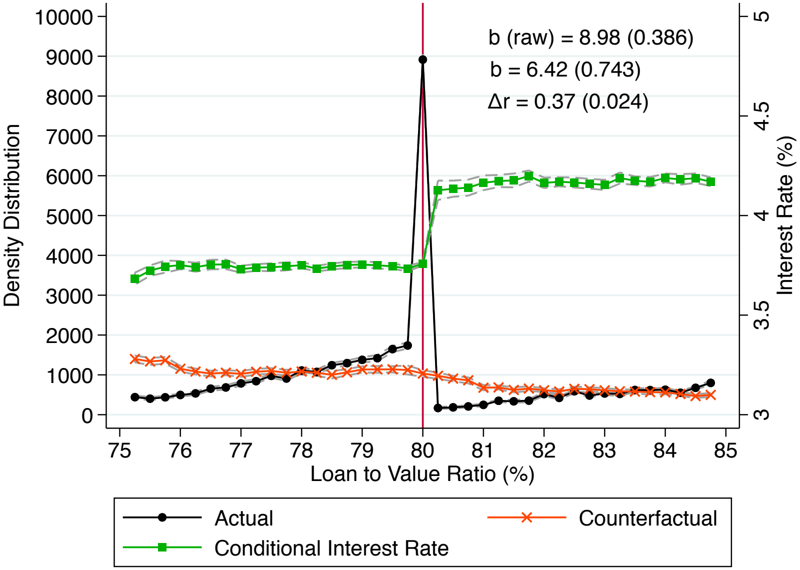
Bunching Estimation at the 80% LTV Notch



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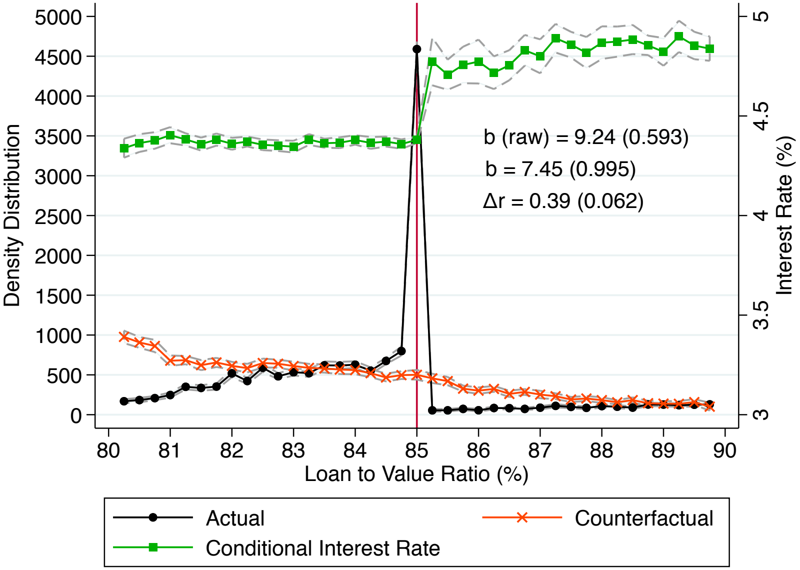
Bunching Estimation at the 85% LTV Notch



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Setup of Lifecycle Model

- Epstein-Zin preferences over housing H_t and non-durables c_t:

$$V_t = \left(\left(c_t^{\alpha} H_{t+1}^{1-\alpha} \right)^{\frac{\sigma-1}{\sigma}} + \delta \left(E_t \left\{ V_{t+1}^{1-\gamma} \right\} \right)^{\frac{1}{1-\gamma} \frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

  - σ is EIS, γ is relative risk aversion, α share of housing in consumption.
- Bequest movtive: $V_{T+1} = \Gamma W_{T+1}$
- Income y_t
- Discrete choice over three values of housing quality.
- House price P_t, consumption goods numeraire.
- Liquid assets L_t with zero nominal return and constraint $L_t > 0$
- Gross mortgage interest rate is $R_t = 1 + r_t$

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Mortgage Contract

- Origination fee Ω
- Fixed maturity of m years, after which penalizing interest rate kicks in.
- Prepayment penalty as in the UK setting virtually eliminate any early refinancing. Waived if moving.
- Full repayment by age 70.
- Amortization schedule:

$$\mu_t = \frac{1}{70 - Age + 1}$$

- Interest rate is a spread over a base rate R_t^0 that is a notched function of LTV at origination as in the data.

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Budget Constraint

$$c_t = y_t + (1 - \pi_t)\, L_t - L_{t+1}$$
$$+P_t \left((1 - d)\, H_t - H_{t+1}\right)$$
$$+D_{t+1} - R_t D_t - \Omega I_t^{\mathsf{R}}$$

- π: inflation
- d: depreciation
- I_t^R: Indicator =1 if refinancing

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Parameter Values

Parameter		Value	Source
Refinancing Cost	Ω	£1,000	Moneyfacts
House Price Process	Autocorrelation ρ_h	0.875	Nationwide
	Trend p_1	0.006	mortgage data
	Variance σ_p^2	0.006	1974–2016
Quadratic lifecycle	linear	1,360	Her Majesty's
income profile coefficients	quadratic	14	Revenue & Customs
Unemployment probability		5%	Historical average
Replacement Rate		60%	Benefit formulas
Future Bank of England policy rate		Calibrated to yield curve	
Inflation expectations		2%	Bank of England target
Bequest motive	Γ	0.1	Internally calibrated
Mortgage amortization rate	μ_t	1 / (70 - Age + 1)	Moneyfacts
Risk aversion	γ	2	Literature
Housing depreciation	d	0.025/annum	HardingEtAl2007
Discount factor	δ	0.96	Literature

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