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. 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

 $\blacktriangleright~{\rm EIS}\approx 0.1$ 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:

$$r_{i} = f (LTV_{i}) + \beta_{1} \text{lender}_{i} + \beta_{2} \text{type}_{i} \otimes \text{dur}_{i} \otimes \text{month}_{i} + \beta_{3} \text{repayment}_{i} + \beta_{4} \text{reason}_{i} + s (\text{term}_{i}) + \nu_{i}$$

Adding borrower demographics have little impact on schedule

Mortgage Interest Schedule



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 ⇒ Passive LTV: LTV immediately before refinancing
- Counterfactual LTV distribution: Passive LTV distribution + equity extraction distribution for non-bunchers



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:

$$c_1 = \left(\delta R\right)^\sigma c_0$$

 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^{\ast}

 $\mbox{Interest rate} \quad R \qquad \quad \mbox{for} \quad \lambda \leq \lambda^*$

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 $R + \Delta R$:

$$V^{I}(\sigma, \delta, \Delta\lambda, \Delta R, \mathbf{x}) = \frac{\sigma}{\sigma - 1} \left(P_{0}H\right)^{\frac{\sigma - 1}{\sigma}} \frac{\left(\delta^{\sigma} \left(R + \Delta R\right)^{\sigma - 1} + 1\right)^{\frac{1}{\sigma}}}{\left(\delta R\right)^{\sigma - 1}} \times \left(\left(\frac{\left(\delta R\right)^{\sigma}}{R + \Delta R} + 1\right) \left(\frac{y_{1}}{P_{0}H} + \Pi_{1}\right) - \left(\left(\delta R\right)^{\sigma} + R\right) \left(\lambda^{*} + \Delta\lambda\right)\right)^{\frac{\sigma - 1}{\sigma}}$$

Value of bunching at λ_* at rate *R*:

$$V^{N}(\sigma, \delta, \Delta\lambda, \mathbf{x}) = \frac{\sigma}{\sigma - 1} \left(P_{0}H\right)^{\frac{\sigma - 1}{\sigma}} \times \left(\frac{1}{(\delta R)^{\sigma}} \left(\frac{y_{1}}{P_{0}H} + \Pi_{1} - R\lambda^{*} - \left((\delta R)^{\sigma} + R\right)\Delta\lambda\right)^{\frac{\sigma - 1}{\sigma}} + \delta \left(\frac{y_{1}}{P_{0}H} + \Pi_{1} - R\lambda^{*}\right)^{\frac{\sigma - 1}{\sigma}}\right)$$

1

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

$$\begin{split} F\left(\sigma,\delta,\Delta\lambda,\Delta R,\mathbf{x}\right) &\equiv V^{N}\left(\sigma,\delta,\Delta\lambda,\mathbf{x}\right) - V^{I}\left(\sigma,\delta,\Delta\lambda,\Delta R,\mathbf{x}\right) = 0,\\ \text{where } \mathbf{x} &= \Big\{R,\lambda^{*},\frac{y_{1}}{P_{0}H} + \Pi_{1}\Big\}. \end{split}$$

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 $LTW \equiv \frac{P_0H-W_0-y_0}{y_1+(1-d)P_1H}$, 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



EIS Estimates

Statiatia	Notch					
Statistic	60	70	75	80	85	Pooled
Panel A: Bunching Evidence						
r(%)	3.17 (0.01)	3.25 (0.00)	3.44 (0.00)	3.76 (0.00)	4.38 (0.01)	3.42 (0.01)
$\Delta r(\%)$	0.10 (0.01)	0.21 (0.01)	0.33 (0.02)	0.37 (0.02)	0.39 (0.06)	0.25 (0.01)
b	0.96 (0.17)	2.94 (0.26)	6.86 (0.39)	6.42 (0.74)	7.45 (0.99)	4.45 (0.20)
a	0.58 (0.05)	0.21 (0.02)	0.30 (0.03)	0.15 (0.02)	0.08 (0.03)	0.29 (0.01)
b_{Adj}	2.31 (0.49)	3.73 (0.35)	9.87 (0.60)	7.59 (0.89)	8.11 (1.16)	6.30 (0.30)
$\Delta \lambda_{Adj}$	0.67 (0.14)	1.06 (0.09)	3.32 (0.18)	2.68 (0.32)	3.71 (0.70)	1.93 (0.09)
r* (%)	13.20 (1.11)	11.78 (0.62)	10.35 (0.46)	9.71 (0.47)	7.18 (0.81)	10.92 (0.27)
Panel B: Elasticities						
EIS σ	0.03 (0.01)	0.03 (0.00)	0.17 (0.02)	0.08 (0.02)	0.13 (0.05)	0.07 (0.01)
Reduced-form ε	0.53 (0.01)	0.53 (0.00)	0.60 (0.01)	0.56 (0.01)	0.58 (0.02)	0.55 (0.00)

Little Heterogeneity in the EIS

Coveriete	Quartile				
Covariate	1	2	3	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 ⇒ 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

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

Robustness

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



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



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 $R_t = 1 + r_t$



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 R⁰_t that is a notched function of LTV at origination as in the data.



Budget Constraint

$$c_{t} = y_{t} + (1 - \pi_{t}) L_{t} - L_{t+1}$$
$$+ P_{t} ((1 - d) H_{t} - H_{t+1})$$
$$+ D_{t+1} - R_{t} D_{t} - \Omega I_{t}^{\mathsf{R}}$$

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



Parameter Values

Parameter		Value	Source	
Refinancing Cost	Ω	£1,000	Moneyfacts	
House Price Process	Autocorrelation $ ho_h$ Trend p_1 Variance σ_p^2	0.875 0.006 0.006	Nationwide mortgage data 1974–2016	
Quadratic lifecycle income profile coefficients	linear quadratic	1,360 14	Her Majesty's 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	Г	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	

