Monetary Policy, Household Debt and Consumption: Evidence from Natural Experiments

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(Preliminary draft. Please do not quote without the permission of the authors)

Introduction

- Estimating the causal effect of monetary policy on consumption via mortgage refinancing channel
- Monetary policy is hard to identify empirically given the endogenous nature of policy decisions
- Even more difficult to estimate its transmission in different states of the economy, and finer levels of granularity cross-sectionally
- This paper builds a "natural experiment" approach to identifying the MP effect at a very granular level
- Use staggered refinancing timing of UK mortgages to construct 6.7 million natural experiments across time and space to estimate the causal impact of interest rate change on borrowing and consumption
- Each natural experiment represents household i, with a mortgage of deal-length n_i (2/3/5) that expires at time t to generate an interest rate shock Δr_{it}.

What this paper is trying to do

- Provide a new natural experiment-based approach to estimate the effect of monetary policy at the *individual* level on borrowing and consumption, every month
- The NE approach enables estimation of *state-contingent* effects, e.g.: Is the effect larger in periods of high unemployment? Is it stronger in tightening cycle versus easing cycle?
- The NE approach enables estimation of monetary policy effects at a very granular level, e.g.: Is the monetary policy effect stronger if households have higher duration assets?
- Does monetary policy pass-through depend on supply-side restrictions, like regional housing constraints?
- Does the magnitude of monetary policy pass-through depend on a household's leverage - potentially generating forces like "indebted demand"?
- How important is the "financial accelerator" channel of monetary policy, i.e. the effect that comes through monetary policy impacting asset valuations?
- How do monetary policy effects aggregate to regional and economy-wide level?
- Can we use these tools to forecast better, and to better forecast the effects of potential monetary policy choices?

Connection to Literature

- Staggered refinancing opportunities in the UK mortgage market (Cloyne, Huber, Ilzetzki, and Kleven, 2019)
  - Estimate the effect of monetary policy on both borrowing and consumption
  - Focus on different outcomes
- Effect of interest rate cuts on consumption using natural experiments (Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao, 2017)
  - Estimate at all points in time
  - Therefore, can estimate state dependence
  - Comprehensive measure of consumption
- Effect of monetary policy on consumption using aggregate data (Romer and Romer, 2004; Gertler and Karadi, 2015; Boivin, Kiley, and Mishkin, 2010; Tenreyro and Thwaites, 2016)
  - Focus on specific refinancing channel
  - Use natural experiments to difference out confounding variables
- Refinancing channel of monetary policy using structural models (Wong, 2019; Berger, Milbradt, Tourre, and Vavra, 2021; Eichenbaum, Rebelo, and Wong, 2022)
  - Reduced form empirical approach

Outline

Data

1. Mortgage Dataset (PSD)
   - Administrative data collected by UK Financial Conduct Authority
   - Snapshot every 6 months of universe of outstanding mortgages in UK (approx 8M at any point in time - and create monthly panel from it)
   - Timeframe: 2015-2023 - so capture both easing and tightenting cycle
2. Consumption Dataset
   - Data from two personal finance apps
   - ClearScore (2018-2023) has information for around 300k mortgagors
   - Money Dashboard (2015-2021) has information for around 100k mortgagors
   - Observe every transaction by every household with detailed descriptions

Consumption Data Comparison

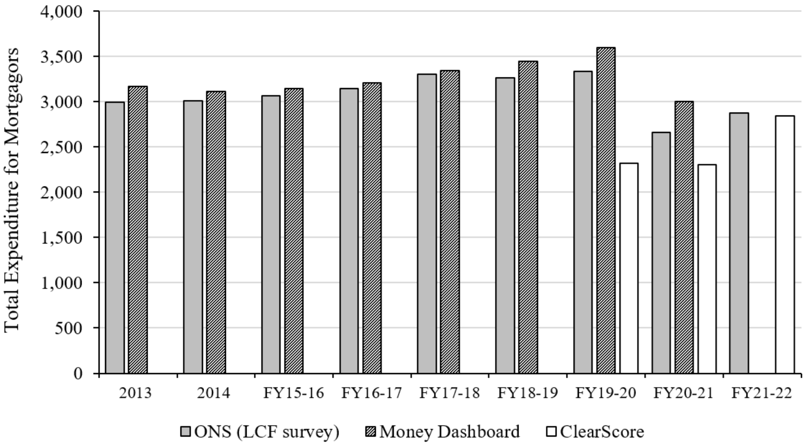


Figure: Consumption Average Representativeness

Consumption-Mortgage Data Representativeness

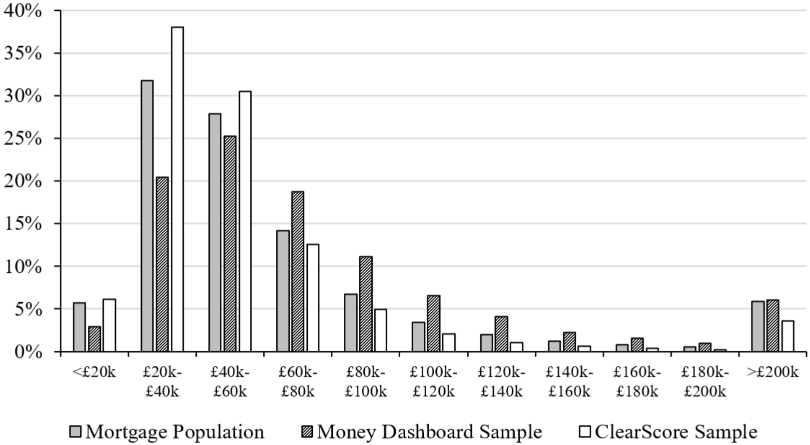


Figure: Consumption Income Representativeness

Rates Over Time

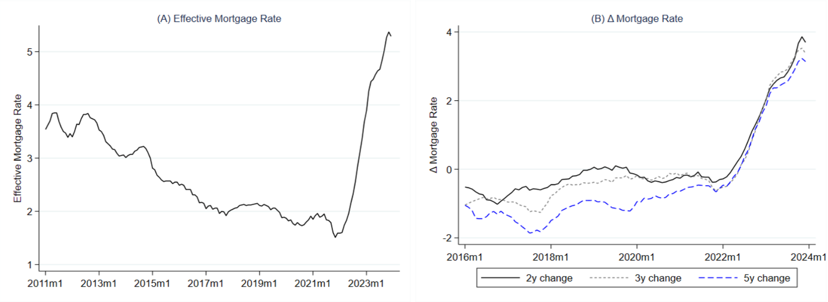


Figure: Rates Over Time

Refinancing in the UK Mortgage Market

- Approximately 90% of mortgagors choose fixed rate interest rate mortgages
- Mortgages have deal lengths typically of 2, 3, and 5 years during which there are severe penalties for refinancing
- At the end of the deal, there is a strong incentive to refinance and start a new mortgage deal at the new rate available

$\rightarrow$ Strong incentive to refinance at staggered + predetermined intervals

Reversion Rate and Refinance Incentives

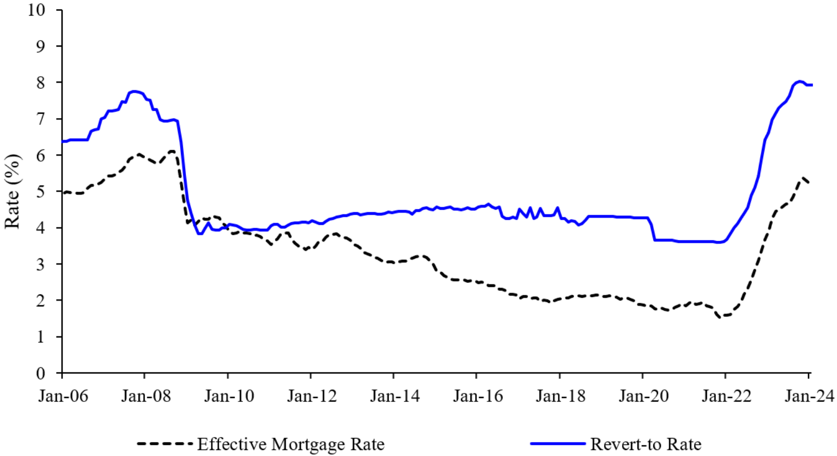
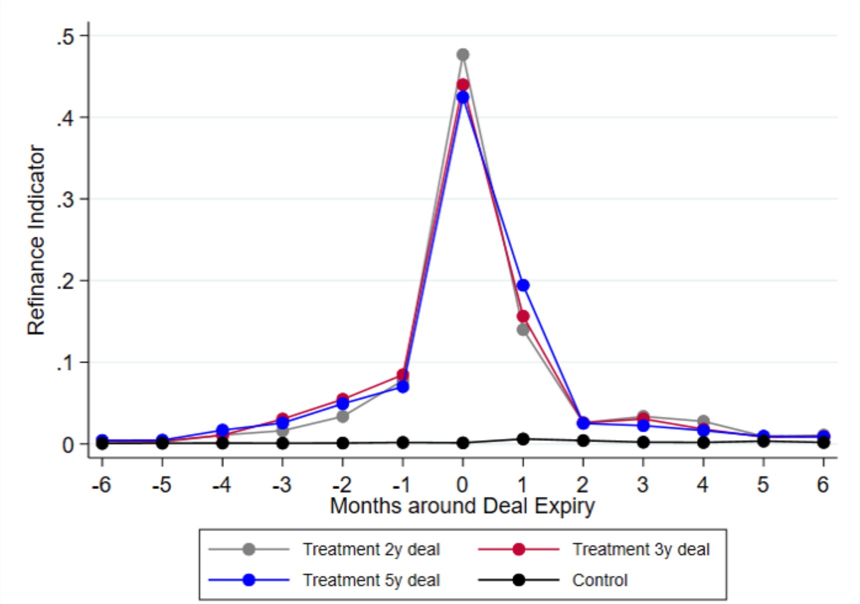


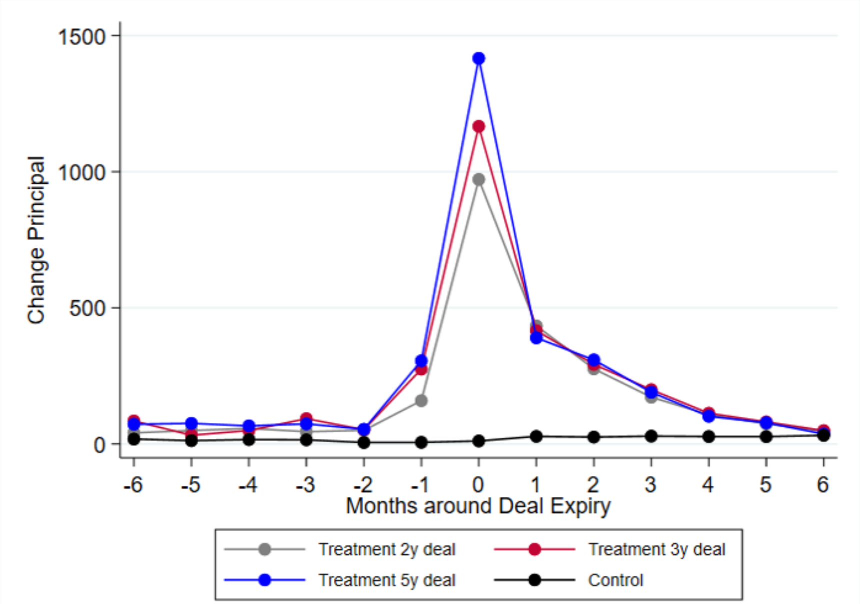
Figure: Reversion Rate and Refinance Incentives

Outline

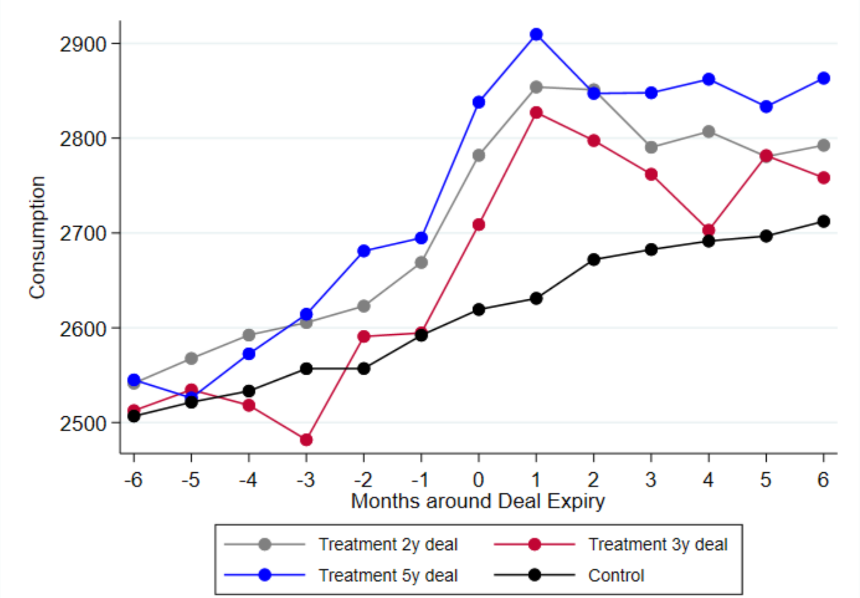
Event Study Representation of Refinancing Propensity



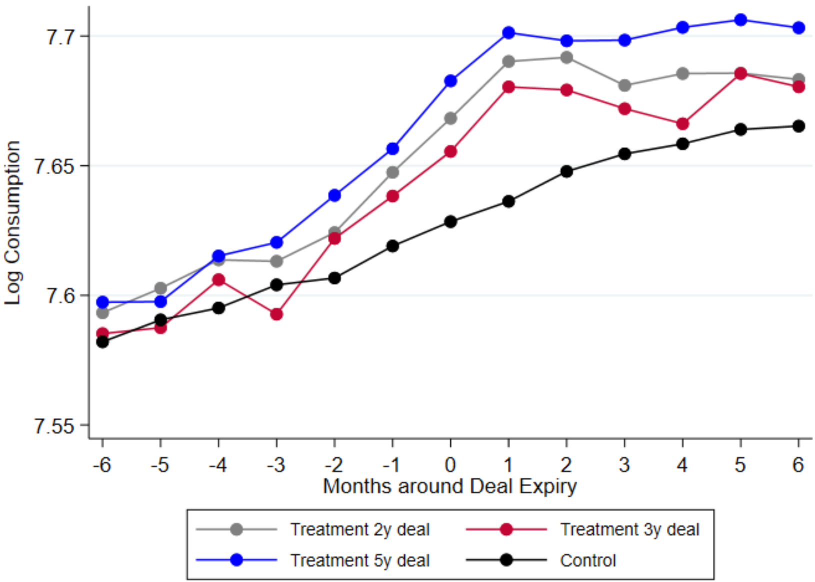
Borrowing around Refinancing



Consumption around Refinancing



Log Consumption around Refinancing



Outline

Potential variation for identifying interest rate change

1. Across deal length-n at a point in time
2. Within a deal length-n over "local time"
3. Variation in Banks' interest rate offer schedules
4. Non-linearities in economy-wide interest rate change

- Today we'll largely focus on the first one

Constructing Natural Experiments

- For each of the 6.7 million treated mortgages i triggered at time t, we construct outcomes,

$$y_{it}^{ST,DL} = y_{it}^{t-n_i,n_i} \qquad \text{(for } n_i = 2,3,5\text{)}$$

  - y could be borrowing or consumption at the individual level
  - $ST = t - n_i$: start time of the deal
  - $DL = n_i$: deal length for treated property i

- We consider control properties j, with outcomes $y_{jt}^{t-n_i,n_i+k}$ where $k \geq 1$
  - These are properties that start their mortgage at the same time as i but are not triggered at time t
  - Define $\bar{y}_{it}^{t-n_i,n_i+k} = \frac{1}{J}\sum_{j=1}^{J} y_{jt}^{t-n_i,n_i+k}$ where J is the number of controls for i

- Then for each natural experiment i, we have a diff-in-diff:

$$\underline{\Delta} y_{it} = \Delta y_{it}^{t-n_i,n_i} - \Delta \bar{y}_{it}^{t-n_i,n_i+k} \tag{1}$$

Decomposing The Difference-In-Difference Estimator

- $\underline{\Delta} y_{it}$ has two components:
  1. Liquidity effect
  2. Interest rate effect

- We can decompose these two components:

$$\underline{\Delta} y_{it} = \beta_t^1 + \beta^2 \Delta r_{it} + \epsilon_{it} \tag{2}$$

  where $\Delta r_{it} = r_t - r_{t-n_i}$ is the change in interest rate over the holding period
  - Variation in Δr_{it} from varying deal-lengths $\rightarrow$ estimate β^2 at point in time.

- β^2 measures the **monetary policy via refinancing**
  $\rightarrow$ All shocks that do not operate through refinancing are "differenced out" by the control group
  - E.g. general equilibrium movements in labor income, confidence shocks, etc.

- **Identification assumption**: no shocks that disproportionately affect refinancers + correlate w/ rates
  - Robustness: instrument for Δr_{it} w/ high frequency monetary shock, or unexpected long-run component

Advantages of the natural experiment approach

- There are 6.7M natural experiments over our sample period, so β^2 can be estimated at a very granular level, and at a point in time
- e.g. we can estimate β^2_{Xt} - for time t and cross-sectional characteristic X, such as asset duration, household attribute, or location
- The time series dimension allows us to estimate state-contingent monetary policy responses - e.g. is response stronger in periods of high unemployment, or tightening versus easing cycle?
- The cross-sectional granularity allows us to estimate the pass-through of monetary policy based on asset duration, regional housing supply, household leverage, or through the "financial accelerator" channel: All questions of economic importance

Single Equation Representation

- Instead of first constructing 6.7M natural experiment observations, we can pool control and treatments into a single equation, and estimate:

$$\Delta y_{it} = \delta_{t-n_i} + \gamma^1 \mathbb{1}_{trigger_t^i} + \gamma^2 \mathbb{1}_{trigger_t^i} \cdot \Delta r_{it} + \gamma^3 \Delta r_{it} + \epsilon_{it} \tag{3}$$

  where δ_{t-n_i} are start time of mortgage fixed effects.

  We can further force treatment-control comparison to be within smaller cross-sectional cells by interacting the relevant variable (e.g. local area identifier) with δ_{t-n_i} fixed effects.

- Mapping: $\gamma^1 \Rightarrow \beta^1$, and $\gamma^2 \Rightarrow \beta^2$

- As before, we can estimate the monetary policy causal effects at a more granular level γ_t^{2X}

Control-Treatment Comparison

	Treatment	Control	Treatment-Control	
			No FE	Time FE
	(1)	(2)	(3)	(4)
Age (Years)	42.674***	42.445***	0.229*	0.037
Loan Value (£s)	164,877***	164,477***	400.056	533.967
Household Income (£s)	60,342***	60,499***	-156.939	-297.462
Home Value (£s)	335,785***	328,929***	6,855.511***	4,307.569**
Term (months)	251.505***	253.484***	-1.979	-0.370
Mortgage Interest Rate (%)	2.333***	2.304***	0.029	0.061**
LTV Ratio	53.532***	54.836***	-1.303***	-0.768*
LTI Ratio	2.871***	2.883***	-0.012	-0.003
DSR Ratio	17.431***	17.457***	-0.026	-0.001
Observations	6,769,712	7,491,003		

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

*Very large sample, hence even small differences are significant at times.

Outline

Data and Setting

Natural Experiment

Identifying Monetary Policy via Refinancing

Results

In Progress and Conclusion

Effect of interest rate on borrowing

	Change Principal			Change Log Principal		
	OLS	OLS	Refi IV	OLS	OLS	Refi IV
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	2258.94***		2287.60***	0.94***		0.96***
	(94.63)		(92.78)	(0.06)		(0.06)
ΔMortgage Rate	-792.08***	-1668.87***	-874.58***	-0.61***	-2.37***	-0.67***
	(96.58)	(424.51)	(103.61)	(0.07)	(0.33)	(0.08)
Observations	6769712	6769712	6769712	6760819	6760819	6760819
Adjusted R^2	0.001	0.002	0.001	0.001	0.003	0.001
K-Papp F-Stat			22094.74			22124.67
Trigger Month FE	No	Yes	No	No	Yes	No

Trigger month clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01.$

Effect of Interest Rate on Mortgage Borrowing: Rate IV

	High Frequency Shocks			Long Term Shocks		
	Change Principal	Change Log Principal	ΔMortgage Rate	Change Principal	Change Log Principal	ΔMortgage Rate
	(1)	(2)	(3)	(4)	(5)	(6)
ΔMortgage Rate	-2333.03***	-3.10***		-2461.77***	-3.12***	
	(453.75)	(0.48)		(465.43)	(0.47)	
HF Mon Pol Shocks			2.08***			
			(0.10)			
LT Rate Shocks						0.27***
						(0.01)
Observations	6769712	6760819	6770378	6706305	6697442	6706964
Adjusted R^2	0.000	0.001	0.975	0.000	0.001	0.981
K-Papp F-Stat	456.73	456.29		337.75	337.29	
Trigger Month FE	Yes	Yes	Yes	Yes	Yes	Yes

Trigger month clustered standard errors in parentheses
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Effect of Debt Service on Mortgage Borrowing

	Change Principal				
	(1)	(2)	(3)	(4)	(5)
Constant	2258.94***	2270.03***	1721.74***	1641.17***	1633.93***
	(94.63)	(8.19)	(76.79)	(186.29)	(211.44)
ΔMortgage Rate	-792.08***	-1674.58***	476.98***	486.10***	-809.60*
	(96.58)	(426.29)	(74.04)	(72.13)	(443.24)
ΔMortgage Rate x Pre Principal			-0.77***	-0.78***	-0.80***
			(0.08)	(0.08)	(0.07)
Pre Principal			0.00***	0.00***	0.00***
			(0.00)	(0.00)	(0.00)
Observations	6769712	6713320	6769712	6713320	6713320
Adjusted R^2	0.001	0.003	0.003	0.004	0.005
House Value FE	No	Yes	No	Yes	Yes
Trigger Month FE	No	Yes	No	No	Yes

Trigger month clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01.$

Effect of Interest Rate on House Prices

	Regional HPI			Freehold	Leasehold	FH & LH
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Mortgage Rate	-19.47***	-18.28***		-17.04***	-14.36***	
	(0.60)	(0.64)		(0.55)	(0.57)	
Δ Mortgage Rate		-3.77***	-3.69***			
x Share Dev. Land		(0.44)	(0.46)			
Δ Mortgage Rate x $\mathbb{I}$(Freehold)						-3.09***
						(0.39)
Observations	5827288	5827288	5827175	3703695	738924	4225317
Adjusted R^2	0.547	0.673	0.748	0.612	0.327	0.977
Trigger Month FE	Yes	Yes	No	Yes	Yes	No
Start Month x Trigger Month FE	No	No	Yes	No	No	No
Lad FE	No	Yes	Yes	No	No	No
Start Month x Trigger Month x Lad FE	No	No	No	No	No	Yes
Tenure x Trigger Month FE	No	No	No	No	No	Yes

Trigger month clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$.

Financial Accelerator - Interest Rate on Borrowing (RF)

	Change Principal		Change Log Principal		Change Principal		Change Log Principal	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	2780.45***		1.27***		2599.04***		1.12***	
	(38.93)		(0.02)		(19.18)		(0.01)	
Δ Mortgage Rate	-1228.79***		-2.23***		-1024.83**		-1.49***	
	(436.58)		(0.34)		(513.73)		(0.39)	
Δ Mortgage Rate	-1697.45***	-1703.94***	-0.58***	-0.57***				
x Share Dev Land	(164.92)	(159.76)	(0.07)	(0.07)				
Δ Mortgage Rate					-846.85***	-1193.38***	-0.80***	-0.97***
x $\mathbb{I}$(Freehold)					(201.77)	(261.51)	(0.14)	(0.19)
Observations	5826725	5826612	5818459	5818346	4471917	4250374	4466505	4244989
Adjusted R^2	0.002	0.006	0.003	0.007	0.003	0.019	0.003	0.019
Start Month FE	Yes	No	Yes	No	No	No	No	No
Start M. x Trigger M. FE	No	Yes	No	Yes	No	No	No	No
Lad FE	No	Yes	No	Yes	No	No	No	No
Start M. x Trigger M. x Lad FE	No	No	No	No	No	Yes	No	Yes
Tenure x Trigger Month FE	No	No	No	No	Yes	Yes	Yes	Yes

Trigger month clustered standard errors in parentheses
$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$.

Financial Accelerator - Interest Rate on Log Borrowing (IV)

	Change Log Principal					
	OLS	Regional IV		OLS	Freehold IV	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.27***			0.27***		
	(0.09)			(0.09)		
Δ Mortgage Rate	-0.71***	-0.82***		-0.65***	2.46*	
	(0.07)	(0.10)		(0.08)	(1.26)	
Log Change House Value	6.53***	17.24***	17.38***	7.66***	27.93***	31.22***
	(0.64)	(2.50)	(2.68)	(0.70)	(6.56)	(8.46)
Observations	5771770	5771770	5771657	4436865	4436865	4219585
Adjusted R^2	0.002	-0.001	-0.001	0.002	-0.002	-0.001
K-Papp F-Stat		65.299	61.816		50.349	61.480
Start Month x Trigger Month FE	No	No	Yes	No	No	No
Lad FE	No	Yes	Yes	No	Yes	No
Start Month x Trigger Month x Lad FE	No	No	No	No	No	Yes
Trigger Month x Duration FE	No	No	No	No	Yes	Yes

Trigger month clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$.

State Contingent Effect of Monetary Policy

	Change Principal		Change Log Principal		Change Principal	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	2539.39***	2066.78***	1.18***	1.19***	1977.46***	1634.41***
	(139.47)	(172.84)	(0.10)	(0.14)	(106.53)	(183.19)
Δ Mortgage Rate	-925.64***	-1318.10**	-0.73***	-2.71***	346.79***	-327.78
	(108.77)	(581.70)	(0.08)	(0.49)	(86.13)	(606.42)
Δ Mortgage Rate x $\mathbb{I}$(High Unemp)	-521.10	-954.48	-0.33	0.94	-84.35	-410.17
	(477.54)	(769.09)	(0.28)	(0.60)	(396.31)	(800.98)
Δ Mortgage Rate x Pre Principal					-0.77***	-0.78***
					(0.09)	(0.09)
Δ Mortgage Rate x Pre Principal					-0.51**	-0.59**
x $\mathbb{I}$(High Unemp)					(0.24)	(0.23)
Observations	6769712	6769712	6760819	6760819	6769712	6769712
Adjusted R^2	0.001	0.002	0.001	0.003	0.003	0.004
Trigger Month FE	No	Yes	No	Yes	No	Yes

Trigger month clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01.$

Rate Hike Asymmetry of Monetary Policy

	Change Principal		Change Log Principal		Change Principal	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	2164.15***	2556.19***	0.81***	1.78***	1634.93***	1568.32***
	(111.35)	(282.49)	(0.09)	(0.31)	(96.52)	(348.74)
Δ Mortgage Rate	-793.94***	-1618.98***	-0.76***	-2.22***	297.73*	-839.07*
	(123.48)	(441.73)	(0.21)	(0.34)	(151.50)	(444.06)
Δ Mortgage Rate x $\mathbb{I}$(Rate Hike)	-1077.29***	-1010.56	-0.56**	-2.90**	-82.83	673.64
	(196.00)	(1032.51)	(0.26)	(1.14)	(212.60)	(1331.12)
Δ Mortgage Rate x Pre Principal					-0.69***	-0.74***
					(0.06)	(0.08)
Δ Mortgage Rate x Pre Principal x $\mathbb{I}$(Rate Hike)					-0.56***	-0.51***
					(0.13)	(0.14)
Observations	6769712	6769712	6760819	6760819	6769712	6769712
Adjusted R^2	0.001	0.002	0.001	0.003	0.003	0.004
Trigger Month FE	No	Yes	No	Yes	No	Yes

Trigger month clustered standard errors in parentheses
$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01.$

Effect of interest rate on Consumption

	Change Consumption			Change Log Consumption		
	OLS	OLS	Refi IV	OLS	OLS	Refi IV
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbb{I}$(Trigger)	73.4081***	68.5476***	88.9920***	2.5428***	2.3761***	3.0698***
	(12.986)	(14.719)	(15.672)	(0.393)	(0.464)	(0.471)
ΔMortgage Rate	-39.5305***	-45.9635***	-48.0842***	-1.0873**	-1.3202***	-1.3535**
x $\mathbb{I}$(Trigger)	(12.211)	(10.951)	(13.955)	(0.471)	(0.415)	(0.528)
ΔMortgage Rate	11.6765		14.5784	-0.2627		-0.1706
	(13.515)		(13.750)	(0.584)		(0.591)
Observations	123842	123842	123842	123842	123842	123842
Adjusted R^2	0.016	0.025	0.001	0.016	0.033	0.001
K-Papp F-Stat			10353.098			10353.098
Start Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Trigger Month FE	No	Yes	No	No	Yes	No

Trigger month clustered standard errors in parentheses
$^{\star}p < 0.10$, $^{\star\star}p < 0.05$, $^{\star\star\star}p < 0.01$.

Effect of interest rate on types of consumption

	Change Consumption				Change Log Consumption			
	Total	Durable	Nondurable	Services	Total	Durable	Nondurable	Services
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\mathbb{I}$(Trigger)	68.5476***	4.8269*	25.2677***	39.4660***	2.3761***	4.8813***	1.3470**	2.2574***
	(14.719)	(2.857)	(8.500)	(9.051)	(0.464)	(1.364)	(0.635)	(0.617)
ΔMortgage Rate	-45.9635***	-0.1461	-21.7883***	-22.8418***	-1.3202***	-0.9818	-1.0334*	-1.3434***
× $\mathbb{I}$(Trigger)	(10.951)	(2.201)	(6.672)	(7.344)	(0.415)	(1.415)	(0.582)	(0.478)
Observations	123842	123842	123842	123842	123842	120747	123730	123841
Adjusted R^2	0.025	0.018	0.011	0.031	0.033	0.032	0.016	0.045
Start Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Trigger Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Trigger month clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01.$

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Natural Experiment

Identifying Monetary Policy via Refinancing

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Work in progress

- More consumption analysis
- GE and Aggregation of monetary policy transmission via the refinancing channel
- More heterogeneity, using machine learning tools
- Improve prediction and forecasting
- Real-time institutionalize?

Conclusion I

- Monetary policy has large effects on borrowing - the average household absorbs interest rate shock almost one-for-one by adjusting debt service
  - i.e. monetary policy pass-through is contingent on amount of leverage in the system
  - $\Rightarrow$ "indebted demand" given lenders have low MPC, or are foreigners
  - $\Rightarrow$ monetary policy has "limited ammunition" (Mian, Sufi and Straub (2021))
  - The debt service adjustment is stronger in tightening versus easing cycle, and in periods of above median UK national unemployment
  - Leverage is a crucial state variable

Conclusion II

- The "financial accelerator" channel operating via asset prices is the most dominance channel through which monetary policy operates
  - i.e. when interest rate falls, asset prices rise $\Rightarrow$ households borrow more (almost one-for-one by adjusting debt service)
  - Quantifying the financial accelerator effect:

$$\frac{\mathrm{d}b}{\mathrm{d}r} = \frac{\mathrm{d}b}{\mathrm{d}v} * \frac{\mathrm{d}v}{\mathrm{d}r}$$

    where b is log borrowing, r is interest rate and v is log collateral value
  - $\Rightarrow$ (tentatively)

$$\frac{\mathrm{d}b}{\mathrm{d}r} = 17 * (-0.19) = 3.2$$

    almost the same as the direct estimate of $\frac{\mathrm{d}b}{\mathrm{d}r}$!

Conclusion III

- Monetary policy has significant effects on consumption - average consumption rises by 2.2pp for 100bps decline in interest rate in short-run
  - Our consumption data includes 2/3rd of total per capita consumption in Living Food and Cost Survey
- The natural experiment approach, based on the 6.7M experiments, enables us to uncover these effects - something not possible using traditional (e.g. time-series) approaches
- Regional and aggregate estimates in process - as well as forecasting

Time Series Analysis

- Let $w_t^{t-n,n}$ be the share of total mortgages that get triggered at time t, for $n = 2, 3, 5$, etc.
  $\rightarrow$ These can be weighted by total \$ value, or unweighted
- Define:

$$\tau_t = \sum_n w_t^{t-n,n}$$

  so $1 - \tau_t$ mortgages do not get triggered at time t. Let r_t be the average change in interest rate experienced by those triggered.
- We can estimate the local projection,

$$\Delta_h Y_{t+h} = \alpha_h + \beta_h X_t + \sum_{\ell=1}^{P} \gamma_\ell \Delta Y_{t-\ell} + \epsilon_t \tag{4}$$

  - Y_t are aggregate outcomes, such as log GDP_t, log C_t, unemployment, or inflation
  - X_t includes τ_t , Δr_t and the interaction of the two ($\tau_t * \Delta r_t$). It is the coefficient on ($\tau_t * \Delta r_t$) that is of interest

Instrumenting With High-Frequency Monetary Shocks

- Let m_t be a high-frequency monetary policy shock hitting at some time during month t. Then, instrument $\Delta z_t^{t-n,n} = \sum_{j=t-n}^{t} m_j$ can be used to construct an aggregate time t instrument.
- Define,

$$\Delta z_t = \sum_n (w_t^{t-n,n} \cdot \Delta z_t^{t-n,n}) \tag{5}$$

- We can use this instrument to run reduced form and LPIV versions of equation (4)

Cross-Sectional Aggregation

- Given variation in $w_{tc}^{t-n,n}$ across geographic regions c, we can construct Δr_{ct}
- We can now run panel regressions analogous to equation (4)
- Doing so allows us to estimate:
  1. Crowding-in or crowding-out multipliers as in Mian, Sufi & Straub
  2. Dynamic effects at c level

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