

Online Appendix for “Refinancing Cross-Subsidies in the Mortgage Market”

A Dataset Construction

A.1 Primary Data Source: Stock of Owner-Occupier Mortgages

PSD007 includes loan-level information on the universe of mortgages in the owner-occupier or residential segment of the mortgage market. The owner-occupier segment includes first-time-buyers, home-movers, and refinancees who obtain mortgages from regulated financial institutions, such as deposit-taking lenders and building societies. All regulated financial institutions are mandated by law to share this data with the FCA at a semi-annual frequency.

We have data on 6 PSD007 snapshots, reported half-yearly from mid-2015 to end-2017. Table A.1 provides a description of the loan-level variables reported in PSD007 relevant to our study. In each snapshot, we observe the loan balance, original size of the loan, remaining term to maturity, original maturity, and interest rate for each mortgage recorded on the reporting date. The database also includes information on the type of interest rate and whether the mortgage is incentivized (i.e., on a discounted rate), and if so, the remaining period under the incentivized or discounted rate. The types of interest rates reported in the dataset are teaser, discounted, capped, standard variable rate, tracker, and an unclassified other category. In some of our summary statistics, we use the reported interest rate to calculate a spread of the discounted rate over the yield on a nominal zero coupon UK Treasury maturing over the horizon over which the interest rate is fixed.^{A.1}

Table A.2 shows the overall balance of mortgages in 2015H1 by interest rate type and incentivized status. The table shows that a vast majority of the mortgages reported as being incentivized are also reported to be under teaser rates. Most mortgages under discounted and capped interest rates are also reported as being incentivized. However, there are a few discounted and capped mortgages that are reported as being non-incentivized and appear

^{A.1}Discounted mortgages are fixed-term mortgages with a specified period under the discounted rate. In our model and in the data, mortgages automatically switch to the reset rate at the end of the discounted period. For example, in the case of a mortgage with a year remaining on the discounted rate, the spread is calculated over the yield on a nominal zero coupon UK Treasury bill maturing in a year. Reset rate mortgages are variable rate mortgages; the spread for reset rate mortgages is calculated based on the yield on short-term (6 month) UK Treasury bill.

Table A.1: Description of Variables

Variable	Description
Current Loan Balance	Balance as on the date of reporting
Current Interest Rate	Interest rate charged on the mortgage
Spread	Spread over the yield on a nominal zero coupon bond maturing over a horizon comparable to the fixation period for interest rates (0 for mortgages under reset rate).
Original Loan Balance	Original size at the time of mortgage account opening date.
Original Term	Original term to maturity at the time of mort. account opening date.
Remaining Term	Remaining term to maturity.
Remaining Discounted Period	Remaining period under discounted rates.
Borrower Age	Borrower age as on the date of reporting.

Notes: The table above provides a brief description of mortgage level variables reported in PSD007 data relevant to our study.

to have anomalous interest rates (we explain further below). We exclude such mortgages from our sample, and pool all incentivized mortgages reported as teaser, discounted, and capped interest rates into our discounted category in the paper.

Table A.3 shows the average interest rate by interest rate type and incentivized status in the 2015H1 snapshot. Mortgages that we classify as discounted, i.e., incentivized mortgages on teaser, discounted, and capped interest rates have lower average interest rates. Mortgages on reset rates (or Standard Variable Rates, SVRs) have higher average interest rates than these categories. There is a small group of mortgages on reset rates which are also reported as being incentivized, which bear interest rates comparable to that of the non-incentivized reset rate mortgages.^{A.2} We treat all instances of mortgages on reset rates as non-incentivized.

Tracker mortgages are the remaining large category of mortgages. Their interest rates are benchmarked to the contemporaneous Bank of England base rate or LIBOR. Table A.3 shows that the average interest rate of mortgages in this category are lower than other mortgage types. However, this category is distinct from the discounted rate mortgages, as these are not teaser rates fixed for a duration; they are subject to rate fluctuations, and there are rarely transitions from the reset and discounted rate category into this category. As the tracker category is relatively isolated from the other two categories and outside of our model, we restrict our study on cross-subsidies to mortgages under the discounted and reset rate categories.^{A.3}

^{A.2}This is a data issue only in the 2015H1 snapshot.

^{A.3}The total number of mortgages, average interest rates, and outstanding balances reported in Tables

Table A.2: Mortgages in 2015H1: Total Balance by Interest Rate Type and Incentivized Status (in £ billions)

	Incentivized		Total
	No	Yes	
Teaser	11.4	442.6	454.0
Discount	1.3	7.3	8.7
Capped	0.0	0.5	0.5
SVR	208.5	6.1	214.6
Tracker	121.7	90.6	212.3
Other	39.0	0.1	39.1
Total	381.9	547.3	929.2

Notes: The table above shows the total balance in £ billions by type of interest rate, and whether the mortgage is reported as being incentivized in the mortgage snapshot for 2015H1.

Table A.3: Mortgages in 2015H1: Average Interest Rate by Interest Rate Type and Incentivized Status

	Incentivized		Total
	No	Yes	
Teaser	5.83	3.35	3.48
Discount	3.04	3.31	3.26
Capped	4.02	2.91	2.99
SVR	3.79	3.63	3.79
Tracker	2.22	2.16	2.19
Other	2.88	2.80	2.88
Total	3.39	3.15	3.26

Notes: The table above shows the average interest rate by type of interest rate, and whether the mortgage is reported as being incentivized in the mortgage snapshot for 2015H1.

A.2 Borrower Incomes and House Prices

The PSD007 dataset does not include information on current borrower incomes, which are typically reported at mortgage origination. We obtain information at origination from the PSD001 dataset (a dataset similar to PSD007, but from earlier years). We use the same variable used to merge information across stock snapshots (since it uniquely identifies a mortgage) to merge the stock data with the loan origination data. We obtain the latest income reported to the lender at the time of origination (usually the first instance of the

[A.2-A.3](#) are before the data filtering and cleaning steps that we describe in this appendix and in the paper.

mortgage being issued, occasionally captured in a subsequent refinancing round), and scale it using local-area level income indices obtained from the Office of National Statistics to an estimate for 2015H1.

Importantly, the distribution of the year of the reported income recorded at the time of origination does not vary across regions or across income bins. This helps to validate the quality of our loan-level income data, and provides reassurance that our cross-subsidy estimate by income-quantiles in section 5 is not affected by any differential quality of reported income across UK regions.

Similar to income, house prices are typically appraised at origination. In order to compute current house prices, and in particular to obtain current loan-to-value ratios (LTV), we scale house prices observed at origination using local-area-level house price indices, reported by HM Land Registry. These house price indices are available at monthly frequency. In order to match the reporting frequency of the mortgage stock (PSD007), we use house price indices reported in June (for H1), and December (for H2 data). This approach is standard in the literature, and is consistent with lenders’ own adjustments of loan-to-value ratios when households refinance.

A.3 Data Cleaning

In the preceding section, we discussed filtering out mortgages with anomalous interest rate types, tracker mortgages, and mortgages under an unspecified “other” category. We implement further data cleaning steps to filter out observations with anomalous or inconsistent data on remaining discounted period, balance, interest rate, remaining term and borrower age, as well as borrowers who may not be able to refinance because they are underwater, in arrears, highly leveraged or have a loan balance that is too small.

Reported Remaining Discounted Period. Table A.4 shows summary statistics for the remaining period on discounted rates (in years) for discounted mortgages across the six snapshots. The mean and standard deviation of the remaining discounted period is consistent across the snapshots, except 2015H1. This is driven primarily by the misclassification of reset rate mortgages as discounted mortgages in 2015H1, resulting in a mass of mortgages with remaining discounted periods greater than 10 years. These are cases where the remaining term is reported as the remaining discounted period, something not seen in other snapshots.

Table A.4: Remaining Discounted Period in Years

(a) Raw database							
	mean	sd	p10	p25	p50	p75	p90
Rem. discounted period (2015H1)	2.89	5.37	0.42	1.00	1.83	3.33	4.58
Rem. discounted period (2015H2)	2.21	2.27	0.33	0.92	1.75	3.00	4.42
Rem. discounted period (2016H1)	2.15	2.23	0.33	1.00	1.75	2.92	4.33
Rem. discounted period (2016H2)	2.09	2.20	0.42	0.92	1.67	2.83	4.25
Rem. discounted period (2017H1)	2.04	2.19	0.33	0.83	1.50	2.75	4.33
Rem. discounted period (2017H2)	2.11	2.21	0.33	0.83	1.58	3.00	4.50
(b) Filtered database							
	mean	sd	p10	p25	p50	p75	p90
Rem. discounted period (2015H1)	2.11	1.52	0.42	1.00	1.83	3.08	4.25
Rem. discounted period (2015H2)	2.09	1.53	0.33	0.92	1.75	3.00	4.33
Rem. discounted period (2016H1)	2.06	1.51	0.42	1.00	1.75	2.92	4.25
Rem. discounted period (2016H2)	2.01	1.52	0.42	0.92	1.67	2.75	4.25
Rem. discounted period (2017H1)	1.96	1.57	0.33	0.83	1.50	2.75	4.25
Rem. discounted period (2017H2)	2.03	1.65	0.33	0.83	1.58	2.92	4.50

Notes: The above tables show summary statistics for the remaining discounted period in months for discounted mortgages across the PSD007 snapshots. Panel (a) shows the summary statistics for the raw database; panel (b) shows the summary statistics after the filtering steps described in Section A.3.

We reclassify the reset rate (or SVR) mortgages with misreported remaining discounted period as being not incentivized.

In addition, across all snapshots, there are few mortgages with remaining discounted periods less than -1 years, and greater than 11 years. We drop all such observations from the sample. Table A.4 (b) shows that the distribution of the remaining discounted period is similar across the different snapshots after implementing the filtering steps described above.

Reported Balance. Table A.5 reports summary statistics for loan balances across snapshots. It shows that all the moments (including mean and standard deviation) for loan balances in 2017H2 are higher than that for other snapshots. This difference is driven by discounted rate mortgages; the loan balance moments for reset rate mortgages are stable across the snapshots.

We find that the high mean and standard deviation for discounted mortgages in 2017H2 is driven by misreported loan balances for two lenders. Hence, for the discounted mortgages issued by these two lenders in 2017H2, we replace the reported loan balance in 2017H2 with

Table A.5: Loan Balances for Raw and Filtered Databases

(a) Raw database

	mean	sd	p10	p25	p50	p75	p90
Balance (2015H1)	118,143	108,109	29,300	59,534	98,043	149,398	219,929
Balance (2015H2)	119,800	115,850	25,000	57,743	98,198	151,763	227,112
Balance (2016H1)	124,175	121,525	28,302	59,246	99,952	155,683	235,932
Balance (2016H2)	128,213	126,975	29,279	60,250	101,966	160,238	244,876
Balance (2017H1)	130,608	127,003	30,000	60,775	103,092	162,999	250,191
Balance (2017H2)	143,369	148,222	29,357	61,902	108,069	178,562	286,897

(b) Filtered database

	mean	sd	p10	p25	p50	p75	p90
Balance (2015H1)	123,325	98,092	38,770	64,821	101,620	152,765	223,988
Balance (2015H2)	127,332	105,483	38,758	65,237	103,424	157,122	233,834
Balance (2016H1)	130,092	111,117	38,309	65,061	104,278	160,214	241,596
Balance (2016H2)	133,558	116,289	38,336	65,680	106,060	164,432	250,009
Balance (2017H1)	134,998	117,715	37,984	65,622	106,807	166,905	254,782
Balance (2017H2)	140,451	125,369	37,953	66,386	109,479	173,774	269,100

Notes: The above tables show summary statistics for the outstanding balance for mortgages across the PSD007 snapshots. Panel (a) shows the summary statistics for the raw database; panel (b) shows the summary statistics after the filtering steps described in Section A.3.

the estimated amortized loan balance based on the reported loan balance, remaining term, and discounted interest rate of 2017H1.^{A.4}

Reported Interest Rate, Remaining Term, and Age. We drop all instances of negative interest rates, and winsorize interest rates at the 99.9 percentile point for each snapshot to address outliers that clearly arise from misreporting (for instance, interest rates of $>1000\%$). We drop all instances of negative remaining terms, and winsorize the distribution at the 99.9 percentile point for each snapshot to address outliers that clearly arise from misreporting (for instance, remaining term of 9999 months). Finally, we drop all instances of reported negative age of borrowers.

^{A.4}We estimate an amortized loan balance for 2017H2 only for discounted mortgages with at least 6 months on discounted periods in 2017H1. Further, we do this estimation only for mortgages that are on a capital and interest payment plan; i.e. we do not restate the 2017H2 loan balance for the small balance of interest only discounted mortgages in the stock of the two aberrant lenders. Further, we do not restate the loan balance of the newly issued discounted rate mortgages issued by these two lenders which leads to a slightly higher average loan balance and LTV for the 2017H2 snapshot. The higher loan balance for 2017H2 has no bearing on the cross-subsidy estimates in our paper based on data moments from the 2015H1 snapshot.

Table A.6: Proportion of Loans Ineligible for Refinancing

	2015H1	2015H2	2016H1	2016H2	2017H1	2017H2
All	100%	100%	100%	100%	100%	100%
(1) LTV \geq 95	2.3%	1.9%	2.2%	2.4%	2.4%	3.6%
(2) Balance \leq 30000	6.5%	6.5%	6.7%	6.7%	6.9%	6.9%
(3) Non-performing	5.5%	5.0%	3.9%	3.9%	3.8%	3.6%
All excl. (1),(2),(3)	86.4%	87.2%	87.7%	87.4%	87.4%	86.3%

Notes: The table above shows the share of borrowers who fall under (1) to (3). “LTV” refers to the current loan-to-value ratio; “Balance” to the current loan balance; and “Non-performing” includes short-term arrears, loans in forbearance, and loans with a possession order.

A.4 Borrowers Potentially Ineligible to Refinance

Table A.6 shows the proportion of mortgages/loans that are potentially ineligible for refinancing using specific criteria based on loan characteristics such as high LTV, low loan-balances or default status discussed in section 2 in the paper. Together, these filters account for 14% of mortgages in 2015H1, a figure that ranges from 13-14% across the snapshots.

Table A.7 presents an alternate view of the effect of these criteria by showing the proportions of mortgages remaining after filtering by these criteria. The first row titled ‘All’ corresponds to the sample of loans in different snapshots for which we have non-missing data for all variables, and row 4 corresponds to the fraction of this sample that remains after applying the filtering criteria to exclude borrowers that are potentially ineligible for refinancing. The 86.4% figure for 2015H1 corresponds to the sample on which we compute the cross-subsidies in our paper. Table A.7 (b) shows that the spread between the average interest rate paid on reset rate and discount rate mortgages goes down with the application of these criteria.

A.5 Summary of Dataset Construction Steps

Table A.8 shows a reconciliation from the owner-occupier mortgage stock of £ 989 mn in 2015H1 in the UK, to the sample of £ 470 mn mortgages relevant to our study. Column 2 in rows 2-8 corresponds to the effect in £ mn of each step discussed in Sections A.1 - A.4, while columns 3 and 4 show the size of the remaining data in £ mn and mn observations, respectively.

Table A.7: Sample With and Without Mortgages Unlikely to Be Able to Refinance

(a) Percentage of mortgages						
	2015H1	2015H2	2016H1	2016H2	2017H1	2017H2
All	100%	100%	100%	100%	100%	100%
All excl. (1) LTV \geq 95	97.7%	98.1%	97.8%	97.6%	97.6%	96.4%
All excl. (2) Balance \leq 30000	93.5%	93.5%	93.3%	93.3%	93.1%	93.1%
All excl. (3) Non-performing	94.5%	95.0%	96.1%	96.1%	96.2%	96.4%
All excl. (1), (2), (3)	86.4%	87.2%	87.7%	87.4%	87.4%	86.3%
(b) R-r (spread)						
	2015H1	2015H2	2016H1	2016H2	2017H1	2017H2
All	0.50	0.61	0.72	0.61	0.77	0.98
All excl. (1) LTV \geq 95 (3)	0.49	0.62	0.75	0.66	0.82	1.00
All excl. (2) Balance \leq 30000 (5)	0.51	0.62	0.73	0.62	0.79	0.99
All excl. (3) Non-performing (7)	0.46	0.56	0.68	0.57	0.73	0.94
All excl. (1), (2), (3)	0.45	0.58	0.72	0.62	0.80	0.96

Notes: The tables above show the share of borrowers (panel (a)) and the average interest rate spread between mortgages under reset (R) and teaser (r) rates (panel (b)) of mortgages excluding those under the filters (1) to (3). “LTV” refers to the current loan-to-value ratio; “Balance” to the current loan balance; and “Non-performing” includes short-term arrears, loans in forbearance, and loans with a possession order.

Table A.8: Steps in Dataset Construction

	Drop (£M)	£Mn	Mn
Mortgage stock in 2015H1		989	8.7
Drop if non-unique postcode + d.o.b.	60	929	7.8
Drop if not reset/discounted	251	678	5.7
Drop discounted if reported as non-incentivised	13	665	5.6
Drop if not reset/discounted in future snapshots	68	597	5.0
Drop if inconsistent/anomalous	32	565	4.6
Drop if unreported income/region	53	512	4.1
Drop if ineligible to refinance	42	470	3.6
Sample for cross-subsidies		470	3.6

Notes: The above shows the total size of the mortgage stock in 2015H1 (row 1), and the effect of each step in data construction leading up to the sample used for cross-subsidies (row 9).

B Merging Across Stock Snapshots

The high-quality disaggregated information in our database allows us to track mortgages across snapshots. In particular, we use the loan-level information on borrower date of birth and the 6-digit postcode to track mortgages across snapshots. These variables, when combined, provide a unique identifier for each mortgage.

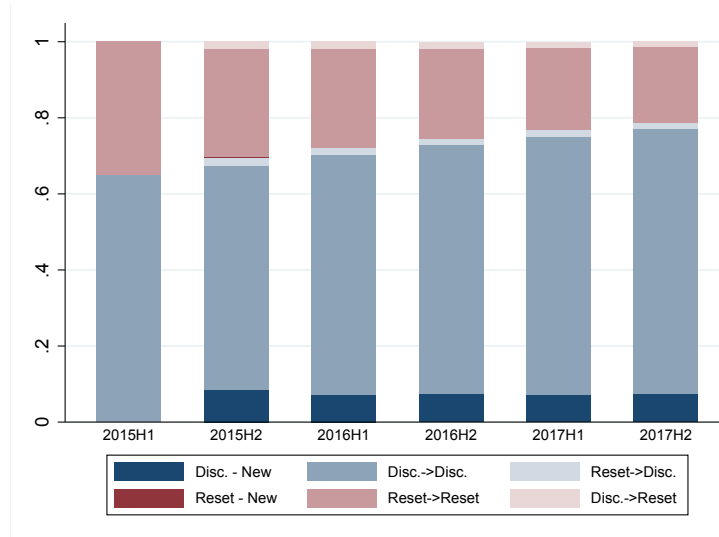
We start with the 2015H1 snapshot as the base, and merge data from subsequent snapshots using this unique identifier. For each mortgage, we can track whether it is discontinued between specific snapshots and whether it originated in any of the snapshots. Exploiting our ability to observe mortgages across snapshots, we also track whether a mortgage transitions across categories (discounted-to-reset rate or reset rate-to-discounted) between snapshots, or whether it continues in the same interest rate category. Across all 6 snapshots, the data track 6.00 million unique mortgages.

Figure B.1 provides a breakdown of discounted and reset rate mortgages in a given snapshot to show the cross-flows between these two mortgage groups across consecutive snapshots. For each snapshot starting 2015H2, we show the discounted (in blue) and reset (in red) mortgages by whether they are new (darkest shade), in the same category in the previous snapshot (lighter shade, e.g. discounted-to-discounted), or cross-flow from a different category in the previous snapshot (lightest shade, e.g. discounted-to-reset).

Observing these cross-flows by tracking mortgages across snapshots underlies one of the key moments we use to estimate our model—the transition probability of reset rate mortgages to be on discounted rates over a 2-year window. Figure B.2 shows the transition probabilities across different categories over 6-month to 24-month horizons for mortgages in the cleaned data for the 2015H1 snapshot (i.e., from 2015H1 up to 2015H2 and 2017H1, respectively). The transition from reset to discounted rate mortgages (R to r in the figure, light blue) increases from 6.73% of the mortgages after 6-months to 16.52% after 24-months.

This transition probability (from reset to discounted rates over the 24 month period) has an interesting pattern across income groups. Figure B.3 shows that this refinancing propensity increases with income (as would be expected given larger average loan balance, as in Table 2, but declines for borrowers above the 80th income quantile. This inversion suggests that total refinancing costs are not homogeneously distributed across the population, and motivate our targetting this moment to capture refinancing costs and benefits across

Figure B.1: Mortgage Flows across Discounted and Reset Rate Categories



The figure above shows the proportion of mortgages under discounted rates (blue) and the reset rate (red) from the mortgage stock as reported at a half-yearly period from 2015H1 to 2017H2. The proportion of mortgages that are new to a snapshot are shown using a darker shade; and the proportion of mortgages that cross categories across snapshots are shown in a lighter shade.

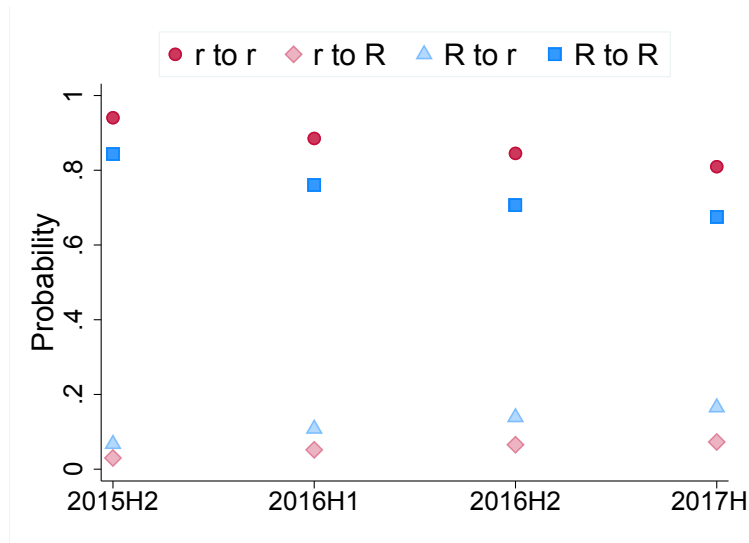
borrowers.

In our sample, on average, around 345,000 mortgages are originated, and around 178,000 mortgage accounts are discontinued every 6 months. Given that new mortgages in each snapshot are predominantly discounted rate mortgages, this leads to an increase in the share of discounted mortgages from 65% in 2015H1 to 78.7% in 2017H2. We discuss potential arguments explaining this shift in Section B.1. In comparison, the proportion of mortgages that flow across the two groups between snapshots is relatively stable.

B.1 Time-Series Evolution of Mortgage Stock

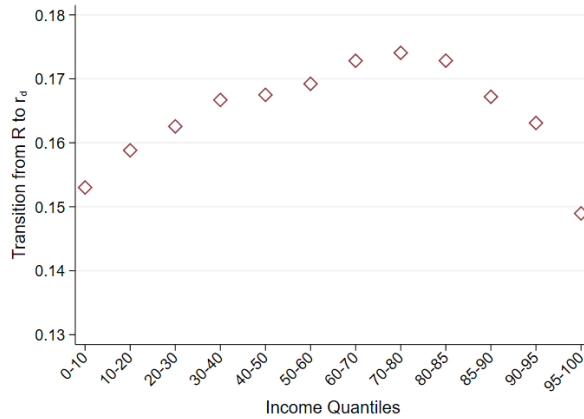
The UK mortgage market has experienced a number of changes from 2015H1 to 2017H2. In particular, Figure B.1 shows a decline in the share of mortgages paying the reset rate. We note that a number of factors could explain the drop in the number of mortgages on reset rates since 2015H1. First, Figure B.4 displays a decline in the average discounted rate, and an increase in the spread between average reset rates and discounted rates after 2015H1. Second, as reported in [Financial Conduct Authority \(2019b\)](#), there has been an increase in lenders' focus on retaining existing customers through internal switching, and an increased

Figure B.2: Transition Probabilities Over Time



Notes: This figure displays transition probabilities between rate types, namely from discounted to discounted, discounted to reset, reset to discounted, and discounted to discounted, over time. The transition probabilities are measured between the share of mortgages in the 2015H1 stock, and 6 to 24 months later (2015H2, 2016H1, 2016H2, 2017H1). Omitted transition probabilities are from discounted or reset rate to account closure.

Figure B.3: Transition from R to r by Income Quantiles



Notes: This figure displays the shares of mortgages that pay reset rates in 2015H1 and discounted rates in 2017H1 across income groups.

role of intermediaries in prompting borrowers to undertake beneficial switches.^{B.1}

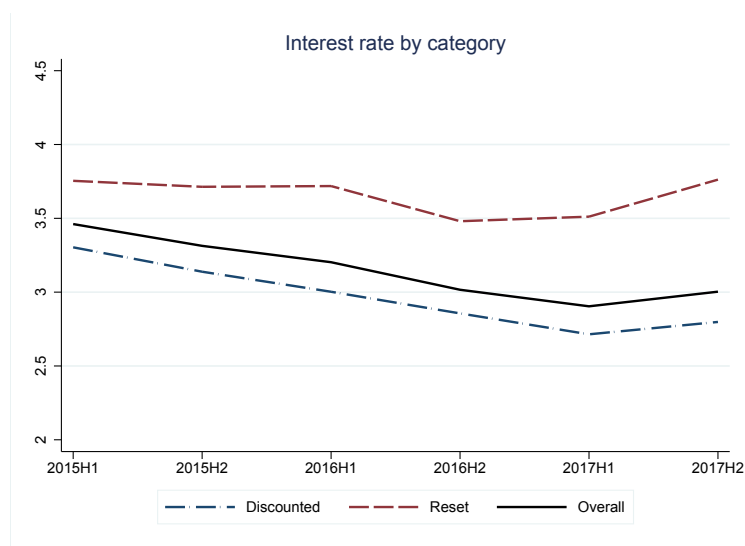
^{B.1}We direct interested readers to more recent changes in the UK mortgage market aimed at facilitating switching at the time of refinancing. For instance, [Financial Conduct Authority \(2020a\)](#) reflects on increased use of technology and other remedies to facilitate switching; and recent policies have made it easier for for

Table B.1: Summary Statistics over Mortgage Snapshots

Snapshots	2015H1	2015H2	2016H1	2016H2	2017H1	2017H2
Average loan size in £						
Discounted	140,647	143,611	145,431	147,815	149,792	152,278
Reset	112,692	111,176	109,285	108,468	107,038	105,799
Average remaining term in years						
Discounted	20.57	20.68	20.71	20.82	20.87	20.90
Reset	16.84	16.53	16.15	15.93	15.62	15.23
Average remaining term (value-weighted) in years						
Discounted	21.67	21.85	21.95	22.11	22.22	22.30
Reset	17.00	16.68	16.30	16.07	15.72	15.33
Average remaining discounted period in years						
Discounted	2.11	2.09	2.05	2.00	1.97	2.03
Average remaining discounted (value-weighted) period in years						
Discounted	2.10	2.10	2.05	1.99	1.95	2.02
Average interest rate						
Discounted	3.30	3.14	3.00	2.86	2.71	2.80
Reset	3.75	3.71	3.72	3.48	3.51	3.76
Average interest rate (value-weighted)						
Discounted	3.20	3.03	2.89	2.75	2.60	2.68
Reset	3.72	3.69	3.69	3.45	3.48	3.74
Average borrower age						
Discounted	41	41	41	41	41	41
Reset	44	45	45	46	46	46

Notes: The table above share summary statistics of mortgages for the stock snapshots from 2015H1 to 2017H2. The sample includes mortgages under two categories - those under discounted rates, and under the reset rate. Please see Appendix Table A.1 for a description of the underlying variables.

Figure B.4: Average Interest Rate of Mortgages under Discounted and Reset Rates



Notes: The figure above shows the equal-weighted interest rate for mortgages under discounted/reset rates in the snapshots of mortgage stock reported at a half-yearly period from 2015H1 to 2017H2.

Table B.1 shows the averages of selected variables in the dataset across snapshots from 2015H1 to 2017H2. The average size of discounted rate loans has risen steadily over time, while the average size of loans on the reset rate has decreased. This is consistent with the change in refinancing incentives over time highlighted above. We also observe an increase in cash-out refinancing as evident in the average loan balance of discounted-to-discounted rate refinanced mortgages. The average remaining term on discounted rate mortgages rises from around 20.6 to 20.9 years (21.7 to 22.3 value-weighted), while the average remaining term on reset rate loans decreases through the sample period, from around 16.8 years to 15.2 years (17.0 to 15.3 value-weighted). The average remaining discounted period on discounted loans is 24 to 25 months in all snapshots of the data, reflecting the modal discounted period of 2 years observed in the data.^{B.2} Finally, we observe an increase in the average interest rate gap between loans on reset rate and discounted rates over time, from 45bp (52bp value-weighted) in 2015H1, to 96bp (106bp value-weighted) in 2017H2. In all sample periods, the loan-balance weighted rate spread is higher than the equal-weighted rate spread. This effect stems mainly from larger discounted rate mortgages having lower rates on average,

financial groups to switch customers from a group's closed book or lender to an active one (Financial Conduct Authority, 2020b), with the objective to make intra-group switching easier), and modified affordability assessments while refinancing for borrowers with up-to-date payments (Financial Conduct Authority, 2019a).

^{B.2}Mortgages under the discounted period are essentially fixed-rate loans. At origination, the most common discounted period is 2 years, followed by 5-year fixed-rate loans.

which is consistent with wealth-based heterogeneity in mortgage refinancing efficiency.

B.1.1 Legacy reset rate mortgages

As mentioned in Section 2.4, our data includes mortgages by two large lenders who offered to cap the reset rate for mortgages issued up to and during the 2007-09 financial crisis at 250 bp. In 2015H1, roughly 90% of all reset rate mortgages for these lenders were on these historically low rates, while the rest of the lenders had raised the interest rate paid when moving to reset rate mortgages to more than 400 bp. Consequently, excluding mortgages by these lenders more than doubles the spread between the average interest paid on reset and discounted mortgages—around 110 bp in 2015H1 (52 bp in our sample including the two large lenders) to 144 bp two years later in 2017H1.

C Mortgage Moments by Region

Table C.1 shows summary statistics across UK regions and devolved administration; we evaluate cross-subsidies by UK regions in Section 5.

The regions are ordered by the average borrower income in the third column. The second column reports the population size, which shows that higher-income regions, such as London and the South East, are also the most populous. Higher-income regions tend to have higher balances as well a larger share of borrowers on the discounted rate, consistent with the patterns that we document across income quantiles in Table 2. One noticeable difference with the patterns in Table 2 is that the highest-income region, London, has the lowest homeownership rate, suggesting rich heterogeneity within and across regions.

Table C.1: Summary Statistics for the Mortgage Stock in 2015H1, By Region

REGIONS	POPULATION (1,000)	INCOME (£)	HOMEOWNERS (%)	BALANCE (£)	DISCOUNTED (%)
NORTHERN IRELAND	1,852	46,236	0.69	88,790	0.59
WALES	3,099	46,443	0.67	100,026	0.62
NORTH EAST (ENGLAND)	2,625	46,465	0.61	93,488	0.60
YORKSHIRE AND THE HUMBER	5,390	47,138	0.63	100,650	0.64
EAST MIDLANDS (ENGLAND)	4,677	49,331	0.67	106,786	0.64
NORTH WEST (ENGLAND)	7,175	49,439	0.64	103,406	0.63
WEST MIDLANDS (ENGLAND)	5,755	50,270	0.65	110,089	0.61
SCOTLAND	5,373	51,463	0.60	102,084	0.61
SOUTH WEST (ENGLAND)	5,472	55,248	0.67	128,260	0.67
EAST OF ENGLAND	6,076	62,041	0.67	146,888	0.69
SOUTH EAST (ENGLAND)	8,949	68,143	0.67	165,072	0.69
LONDON	8,667	85,598	0.49	207,592	0.69

Notes: The table above shows summary statistics of mortgages from the stock data reported in 2015H1, split by UK regions. Regional population for June 2015 is in 1,000s. Appendix Table A.1 contains a description of the underlying variables.

D Prompt and Sluggish Refinancers

In this Appendix, we explore the relationship between refinancing patterns in our data and borrower characteristics. This analysis builds on [Cloyne, Huber, Ilzetzki, and Kleven \(2019\)](#) by evaluating observable differences in the characteristics of borrowers paying different rates; and provides an important insight: that refinancing patterns are an outcome of both observed factors (such as loan balances) and unobserved refinancing costs. These descriptive statistics motivate our modelling strategy, through which we can estimate and analyse interesting variation in hitherto unobservable refinancing costs across borrower types.

To explore refinancing patterns, we first compare “prompt” borrowers who refinance within 6 months of the fixed-rate expiration window, and “sluggish” borrowers who delay refinancing past this point.^{D.1} We conduct this comparison using borrowers whose fixed-rate contracts expired between 2015H1 and 2015H2.

Table [D.1](#) shows that households who refinance promptly typically have larger origination and current loan balances (cross-sectional means are displayed with cross-sectional standard deviations below in parentheses), higher income levels, but comparable remaining terms and LTI and LTV ratios. Whereas prompt refinancers tend to have higher incomes, it is not clear whether their refinancing propensity is driven by their larger loan balances (which provide greater benefits from refinancing) or their unobservable refinancing costs.

We next explore differences in observable mortgage contract characteristics and borrower attributes between mortgages on the discounted and reset rates. Table [D.2](#) compares mortgage and borrower characteristics in the stock of mortgages that pay reset and discounted rates. The table further splits the data on whether the current loan balance is above the median (columns 1 and 2), or below the median (columns 3 and 4), to get a sense of the extent to which refinancing benefits, which scale with mortgage size, drive refinancing behavior.

Table [D.2](#) shows that borrowers on the reset rate have smaller original and current loan balances and shorter remaining terms, consistent with rationally lower incentives to refinance. Correspondingly, the proportion of discounted-rate mortgages is higher for borrowers with larger loan sizes. However, within both high- and low-balance groups, those

^{D.1}This definition of prompt and sluggish will not necessarily correspond to optimal and sub-optimal refinancing, as optimality depends on borrowers’ specific circumstances, as we describe in more detail in the model section.

Table D.1: Refinancing Decisions Due Between 2015H1 and 2015H2

	PROMPT	SLUGGISH	REPAID/MOVED
ORIGINAL LOAN BALANCE	155,221 (107,043)	120,994 (81,381)	158,886 (113,046)
ORIGINAL TERM	23.82 (6.97)	23.33 (7.79)	23.15 (7.78)
CURRENT LOAN BALANCE	143,670 (102,432)	111,216 (77,468)	143,441 (107,417)
CURRENT INTEREST RATE	3.33 (0.98)	3.75 (1.10)	3.38 (1.03)
REMAINING TERM	20.79 (7.47)	20.14 (8.36)	19.77 (8.26)
BORROWER AGE	40.66 (9.42)	41.13 (11.05)	41.13 (10.73)
CURRENT INCOME	59,104 (64,198)	51,332 (120,794)	65,300 (69,529)
CURRENT LTV	57.35 (17.95)	57.10 (20.18)	54.16 (19.43)
CURRENT LTI	2.66 (1.44)	2.50 (1.40)	2.48 (1.36)
N	207,320	49,586	19,482

Notes: The table above compares means and standard deviations (in parentheses) for households whose fixed-rate contract was due to expire between 2015H1 and 2015H2. Column 1 reports households who refinanced within 6 months after their contract expiration date (“prompt”), column 2 reports households who did not refinance in that window (“sluggish”), and column 3 reports households who prepaid the loan and left the sample.

who pay reset rates have higher incomes. This hints at the fact that high-income borrowers could have higher (unobserved) refinancing costs. These patterns emphasize the need for careful consideration of both loan balances and refinancing costs to correctly estimate cross-subsidies across different groups.

Finally, the summary statistics in Table D.2 are consistent with lenders earning greater risk-adjusted returns from borrowers on the reset rate, since they pay higher average rates, but have similar LTVs and LTIs, which are standard indicators of borrower riskiness. This suggests that the dual-rate structure does not serve the function of screening borrowers on the basis of risk.

Table D.2: Characteristics by Rate Type and Loan Balance

	HIGH		LOW	
	DISCOUNTED	RESET	DISCOUNTED	RESET
ORIGINAL LOAN BALANCE	205,634 (117,247)	187,929 (97,522)	82,467 (27,204)	86,351 (32,456)
ORIGINAL TERM	24.84 (6.52)	23.97 (6.42)	21.35 (7.59)	23.04 (6.94)
CURRENT LOAN BALANCE	196,766 (112,791)	176,047 (90,371)	72,114 (20,954)	69,137 (21,058)
CURRENT INTEREST RATE	3.22 (0.93)	3.72 (0.97)	3.41 (0.96)	3.78 (0.98)
REMAINING TERM	22.56 (7.02)	17.53 (6.80)	18.15 (7.86)	16.37 (7.01)
BORROWER AGE	39.47 (8.78)	44.35 (9.32)	42.07 (10.63)	44.49 (10.56)
CURRENT INCOME	74,855 (261,183)	78,754 (109,242)	38,665 (37,069)	41,894 (48,369)
CURRENT LTV	62.76 (17.01)	62.64 (17.07)	51.46 (21.61)	53.32 (22.20)
CURRENT LTI	2.98 (1.61)	2.65 (2.37)	2.21 (1.16)	1.97 (1.06)
N	1,283,633	511,486	1,051,121	743,988
SHARE OF DISCOUNTED	71.5%		58.6%	

Notes: This table compares means and standard deviations (in parentheses) for households across rate types, split by current loan balance. Columns 1 and 2 report values for households with above-median loan balances, and columns 3 and 4 report values for households with below-median loan balances.

E Financial Costs of Mortgages

In this Appendix, we provide a brief discussion on the financial costs of mortgage origination (based on both known features of our institutional setting and origination fees reported in the data) and we compare them to the costs of mortgage origination (which combine financial and psychological costs) estimated using our model.

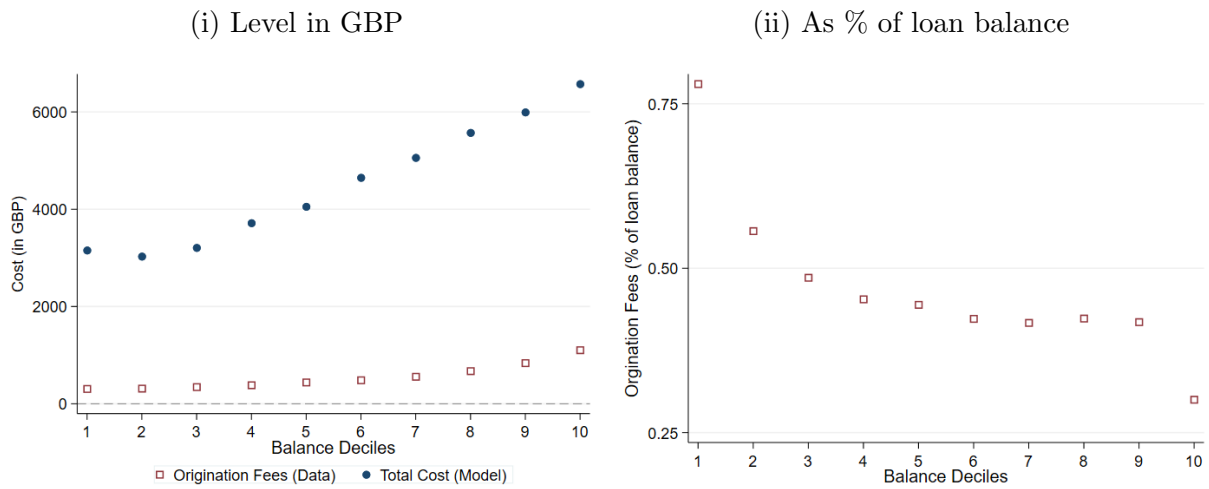
According to UK mortgage advice websites such as MoneySavingExpert,^{E.1} origination cost in the UK are typically comprised of the following (fixed) components: deeds release fee (£50–300), arrangement fee (£0–2,000), booking fee (£100–300, rare), valuation fee (£500–1,500, often waived). This general guidance suggests that origination costs are primarily a fixed cost and do not have a variable component that is proportional to the loan balance. Remortgaging costs have identical compositions (i.e., they are fixed) and similar magnitudes as origination costs.

To validate this pattern of fees in the data, we analyze the relationship between mortgage origination costs and loan sizes using our comprehensive UK administrative data. We use the origination fees reported for all mortgages originated in the UK in 2015 (reported in the FCA dataset PSD001 introduced in Section A.2) to calculate the average fees by loan balance deciles. The loan balance thresholds used to classify the origination data into loan balance deciles are consistent with our estimation sample (which includes the stock of mortgages in 2015, but lacks information on the financial origination costs for mortgages originated before 2015).

Figure E.1 (i) shows a positive relationship between origination fees and loan balances (red squares). However, the slope is quite small and these financial fixed costs are an order of magnitude lower than the origination costs estimated using the model (blue circles) which include both financial as well as psychological costs of refinancing. Further, in Figure E.1 (ii), these financial costs actually decrease as a percentage of the loan balance.

^{E.1}<https://www.moneysavingexpert.com/mortgages/mortgage-fees-stamp-duty/>

Figure E.1: Fees by Loan Balance Deciles



Notes: Panel (i) displays the average origination fees by loan deciles in the 2015 mortgage origination data (red squares) and the average origination costs estimated using the model (blue dots). Panel (ii) displays the origination fees scaled by the average loan balance for each decile.

F Option Value of Staying on Reset Rate

In this Appendix, we evaluate to what extent households not refinancing reflects an optimal option exercise, rather than their refinancing cost. As we explain below, reset rates do not come with prepayment penalties and so allow households to flexibly refinance in case interest rates go down. If there is an option value associated with waiting on the reset rate, it is difficult to interpret k as a behavioral parameter, the need for which is eliminated in the counterfactual. In order to evaluate the option value, we apply a standard approach in the literature and customize it to see if it can deliver an option value that justifies paying the reset rate for short periods, and find that it cannot, for reasonable parameter values.

F.1 Reset Rates and the Option To Refinance

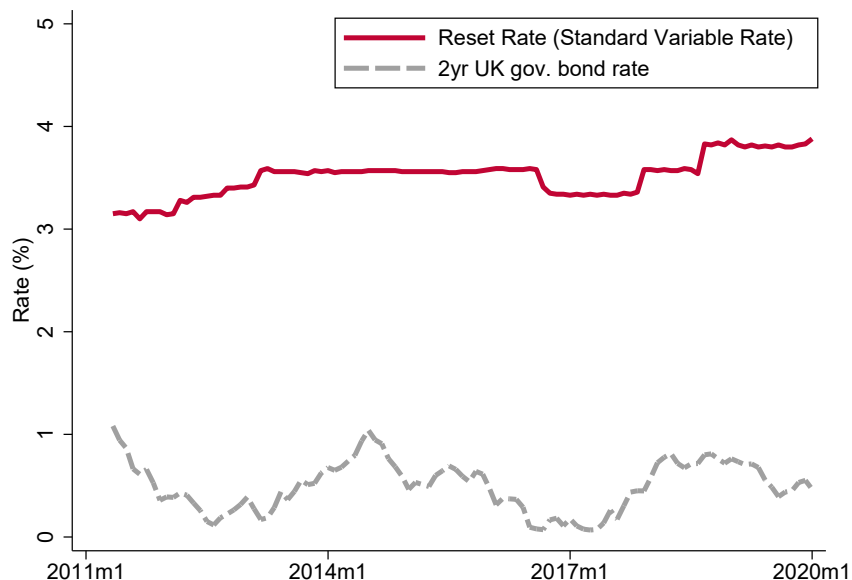
UK mortgages have fixed rates and substantial prepayment penalties over the discounted fixation period, such that households typically lock in the rate and refinance next at the end of the fixation period. The reset rate, also called the “Standard Variable Rate” (SVR), in contrast, allows households to retain the option to refinance flexibly when interest rates go down. Figure F.1 shows the average reset rate and variation in 2-year government bond yields since 2011.

While reset rates do appear linked to underlying UK Treasury rates, they adjust at a slower rate and have less variability. Households incur a cost to retain the option to refinance, which is the difference between this slow-to-adjust and high reset rate R and the discounted rate r that they can currently access in the market. In what follows, we conduct a quantitative assessment of the net benefit of this refinancing option.

F.2 Optimal Refinancing Differential

In a standard refinancing framework with long-term fixed-rate mortgages, households rationally evaluate the present value of interest payments that they make under the new rate into which they refinance, and compare the payments they would make on this rate with those on the rate they would otherwise be in, accounting for any refinancing costs incurred, plus any difference between the value of the refinancing option that they give up, and the value of the new refinancing option that they acquire (Chen and Ling, 1989; Agarwal, Driscoll, and Laibson, 2013). Households optimally exercise their option to refinance when

Figure F.1: Reset Rates Over Time



Notes: This figure shows the average Standard Variable Rate and 2-year UK Treasury bond yield at monthly frequency, as reported by the Bank of England Database.

the new rate is sufficiently lower than the rate they would otherwise bear (the “old rate”). This decision can be characterized using a “threshold,” which is a specific value of the differential between the new and old rates beyond which it is rational to refinance.

Agarwal, Driscoll, and Laibson (2013) derive an analytical solution to this class of refinancing problems. They propose that households should refinance when the difference between the current mortgage interest rate (r_t) and the old rate (r_0), denoted by Δr , is greater than the optimal threshold Δr^*

$$\Delta r^* \equiv \frac{1}{\psi} (\phi + W(-\exp(-\phi))),$$

where $W(\cdot)$ is the principal branch of the Lambert W -function, $\psi = \frac{\sqrt{2(\rho+\lambda)}}{\sigma_r}$, and $\phi = 1 + \psi(\rho + \lambda) \frac{\kappa/M}{(1-\tau)}$. The optimal threshold depends on the real discount rate ρ , the expected real rate of exogenous mortgage repayment λ , the standard deviation of the mortgage rate σ_r , and κ/M , the ratio of refinancing cost and outstanding loan balance.

To make this framework applicable for UK borrowers considering whether or not to refinance into a discounted rate mortgage, we set κ to the median persistent component k_i

of borrowers, £758, a conservative estimate of total refinancing cost, and M as the average loan balance £130,871. σ_r is set to the historical standard deviation of 2-year UK real rates, at 0.0193. We further follow [Agarwal, Driscoll, and Laibson \(2013\)](#) to compute the rate of mortgage repayment as

$$\lambda = \mu + \frac{r_0}{\exp[r_0 T] - 1} + \pi,$$

where μ is the (annual) probability of prepayment, T is the remaining loan maturity, which we set to 30 years, and π is the rate of inflation, which we set to 2%. We set μ to 0.5 to capture the expected holding period of 2 years.^{F.1}

For this representatively calibrated household, the optimal refinancing differential that we obtain is 111 basis points. This estimate provides a quantitative sense of by how much interest rates need to decrease for the refinancing option to be valuable, i.e. to be “in the money”. For comparison, [Figure F.2](#) shows how the optimal refinancing differential would vary by loan size. Intuitively, since the refinancing cost is fixed, the refinancing differential is decreasing in loan size, as the refinancing benefit is scaled by the loan balance. The majority of loans in the stock of mortgages have loan balances that are smaller than £200,000, and so require differentials between around 100 to 150 basis points.

Next, we simulate how likely it is that this refinancing threshold is hit, i.e., how likely the option is to be in the money, and the expected value of the option.

F.3 Simulation of Option Value of Refinancing

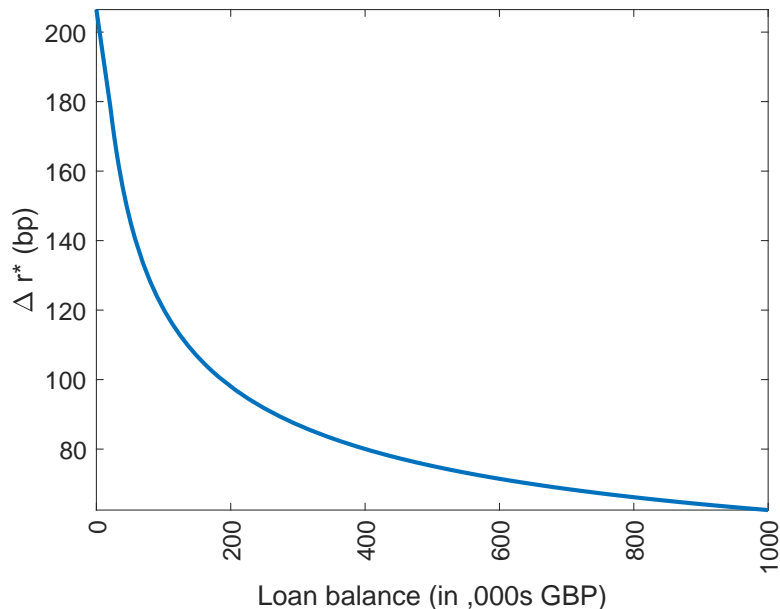
For a given old interest rate r_0 , the optimal refinancing threshold calculated in the previous subsection (i.e., 111 basis points in our calibration) characterizes the level of the current mortgage rate r^* below which it is optimal to refinance. The expected value of the refinancing option is then

$$\begin{aligned} & \int_{-\infty}^{+\infty} (r_0 - r_s) \mathbb{I}_{(r_s \leq r^*)} f(r_s) dr_s \\ &= \int_{-\infty}^{r^*} (r_0 - r_s) f(r_s) dr_s. \end{aligned} \tag{F.1}$$

We can simulate the expected value of this expression by specifying a data-generating

^{F.1}In this framework, the time over which the refinancing benefit accrues is primarily captured via the prepayment probability μ , rather than T .

Figure F.2: ADL Threshold Under Different Loan Sizes



Notes: This figure plots the optimal refinancing threshold using the formula by [Agarwal, Driscoll, and Laibson \(2013\)](#) under the main calibration, when varying the loan balance.

process for interest rates. Suppose interest rates follow a standard AR(1) process:

$$r_t = (1 - \rho_r)\mu_r + \rho_r r_{t-1} + \epsilon_t, \quad (\text{F.2})$$

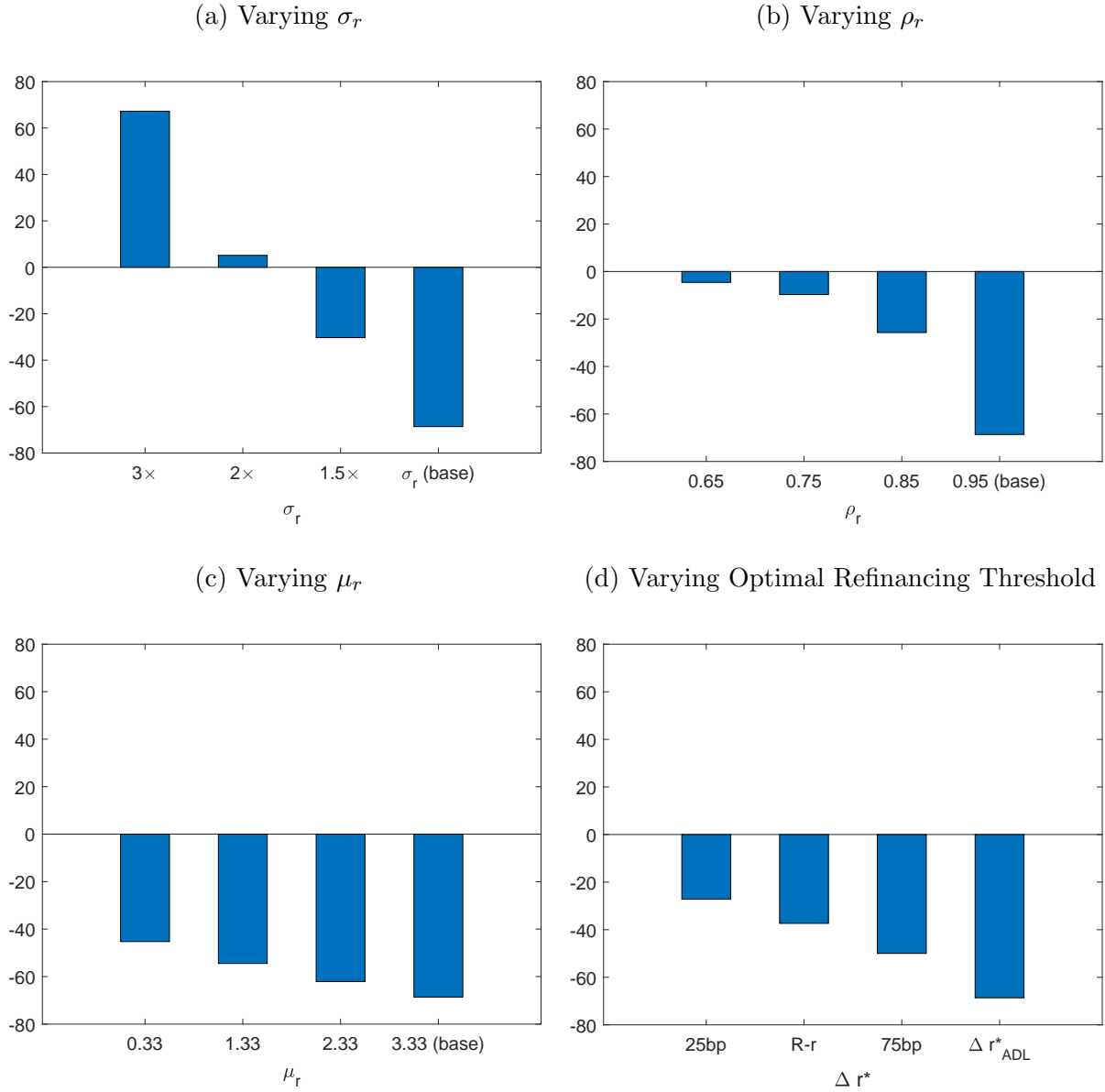
where ϵ_t is a normally distributed white noise shock with mean zero and variance σ_ϵ^2 , and ρ_r is the autocorrelation coefficient. The variance of the white noise shock is related to the variance of interest rates σ_r via $\sigma_\epsilon = \sqrt{\sigma_r^2 \cdot (1 - \rho_r^2)}$.

Households in our setting compare two options. The first is to take out a new 2-year fixed-rate contract right away (subsequently refinancing again after 2 years). The second is to stay on the reset rate and then refinance into a new 2-year fixed-rate contract whenever the optimal refinancing threshold is met. We simulate the expected NPV of such an option exercise, assuming that households can choose to wait up to 2 years to exercise the option to refinance. We then evaluate the NPV over a period of 4 years to ensure that we compare all households' NPV of option exercise over a similar period, regardless of when they fix again within the two-year window.

Figure F.3 shows simulations of the expected NPV of the option under different calibrations of the interest rate process and optimal refinancing thresholds. Panels (a), (b) and (c) show that the NPV is only positive if interest rates are substantially more volatile than they have been historically, by a factor of 2 to 3. Varying the persistence or long-run average of the interest rate process within reasonable ranges are not sufficient to yield a positive value. In addition, Figure F.3d shows the NPV for different assumptions about the refinancing threshold—lowering it to 25 and 75bp rather than calibrated ADL value of 111 bp. We also consider an alternative benchmark, which is a simple rule-of-thumb to refinance whenever the current interest rate makes up for the reset rate differential $R - r$. Under all these scenarios, we find that the expected value of the option remains negative.

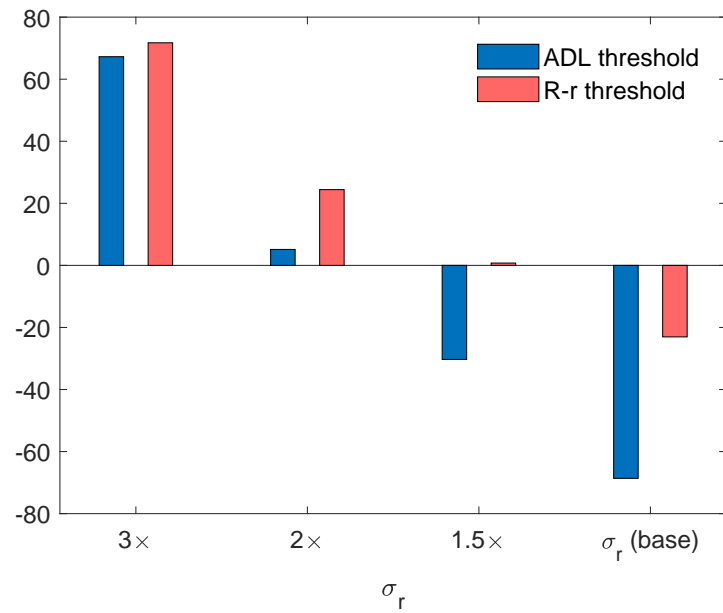
Lastly, Figure F.4 shows that the expected value of the refinancing option is around 20 basis points when households refinance based on the $R - r$ threshold, under a counterfactual interest rate volatility that is twice the historical average. Based on these simulations, we conclude that the option value of staying on the reset rate is not economically significant under a benchmark calibration of interest rates. This is because the cost of retaining the option is very high (this is the spread of the reset rate over the discounted rate) which penalizes waiting, and because the window over which the option can be exercised is relatively short, corresponding to the typical fixation window of 2 years.

Figure F.3: Expected NPV of Refinancing Option on Reset Rate



Notes: This figure displays the simulated net present value of the option to refinance when staying on the reset rate, under different calibrations of the interest rate process and the optimal refinancing threshold.

Figure F.4: Varying Optimal Refinancing Threshold and σ_r



Notes: This figure displays the simulated net present value of the option to refinance when staying on the reset rate, under different calibrations of interest rate volatility and comparing the ADL optimal refinancing threshold with a threshold that corresponds to the difference between the reset and discounted rate.

G Counterfactual Results with Alternative Rates

In this Appendix, we report the results of our counterfactual analyses for alternative interest rates, namely:

1. The average discounted rate, i.e., $r_c = 650$ bps.
2. The rate that yields the same revenue as the composite of the populations on the discounted rate and the reset rate.

More precisely, in the baseline case aggregate lender revenues from all mortgages (on both discounted and reset rates) equal:

$$r_d(Q_0(r_d) + Q_1(r_d)) + RQ_2(R). \quad (\text{G.1})$$

Under the assumption of aggregate lender revenues remaining constant across the two scenarios, the interest rate r_c must satisfy:

$$r_c Q(r_c) = r_d(Q_0(r_d) + Q_1(r_d)) + RQ_2(R). \quad (\text{G.2})$$

In practice, this equality yields $r_c = 698$ bps.^{G.1}

3. The average reset rate, i.e., $r_c = 759$ bps.

The values of the constant interest rate in cases 1 and 3 likely represent lower and upper bounds to interest rates in a counterfactual market with constant rates, respectively, whereas case 2 uses an intermediate value similar to that used in our main analysis of Section 5.

Perhaps not surprisingly, Panel A shows that all reported statistics increase in a market with a constant interest rate equal to the average discounted rate. Interest rates decline for all borrowers, except for those who always refinance, thereby boosting mortgage debt both

^{G.1}When working with multiple groups, we perform the cross-subsidy calculation using the interest rate that satisfies:

$$r_c \sum_{j=1}^J Q_j(r_c) = \sum_{j=1}^J (r(Q_{0,j}(r_d) + Q_{1,j}(r_d)) + RQ_{2,j}(R)), \quad (\text{G.3})$$

where $Q_j(r_c)$ is the aggregate mortgage debt of group j when the interest rate is fixed at r_c . The difference between equations (G.2) and (G.3) is that aggregate revenues are calculated using the heterogeneous parameters across groups. In practice, the difference between the interest rates that satisfy equations (G.2) and (G.3) is only a few bps, with minimal effects on the counterfactuals reported in Table 5.

Table G.1: Market Outcomes with Alternative Constant Interest Rates

	UK-WIDE	INCOME GROUPS	REGIONS
PANEL A: CONSTANT INTEREST RATE=650 BPS			
NUMBER OF MORTGAGES	1.11	1.13	1.13
MEAN INITIAL LOAN AMOUNT	1.05	1.06	1.05
STANDARD DEVIATION INITIAL LOAN AMOUNT	1.05	1.03	1.03
MEAN LOAN BALANCE	1.04	1.06	1.04
STANDARD DEVIATION LOAN BALANCE	1.05	1.04	1.03
CONSUMER SURPLUS	1.12	1.12	1.10
PANEL B: CONSTANT INTEREST RATE=700 BPS			
NUMBER OF MORTGAGES	1.04	1.07	1.04
MEAN INITIAL LOAN AMOUNT	0.94	0.93	0.94
STANDARD DEVIATION INITIAL LOAN AMOUNT	0.92	0.89	0.90
MEAN LOAN BALANCE	0.95	0.93	0.94
STANDARD DEVIATION LOAN BALANCE	0.93	0.90	0.92
CONSUMER SURPLUS	1.01	0.99	0.99
PANEL C: CONSTANT INTEREST RATE=759 BPS			
NUMBER OF MORTGAGES	0.95	0.97	0.93
MEAN INITIAL LOAN AMOUNT	0.82	0.79	0.82
STANDARD DEVIATION INITIAL LOAN AMOUNT	0.78	0.75	0.77
MEAN LOAN BALANCE	0.84	0.80	0.83
STANDARD DEVIATION LOAN BALANCE	0.80	0.76	0.79
CONSUMER SURPLUS	0.88	0.86	0.88

Notes: This table reports the statistics on the mortgage market in counterfactual markets with constant interest rates, as ratios of those of the estimated market with dual interest rates. The statistics in Panel A are calculated using a constant interest rate equal to the average discounted rate. The statistics in Panel B are calculated using a constant interest rate equal to the interest rate that satisfies the equal-revenue equation (G.2). The statistics in Panel C are calculated using a constant interest rate equal to the average reset rate.

at the extensive margin (increasing the total number of mortgages) and at the intensive margin (increases in average initial loan sizes and average loan balances). These outcomes are remarkably similar across the different estimated models, i.e., single versus multiple groups, with the slight difference that the multiple-group models display a higher sensitivity of household participation decisions to interest rates relative to the UK-wide case, and thus a larger increase in the number of mortgages as interest rates decline.

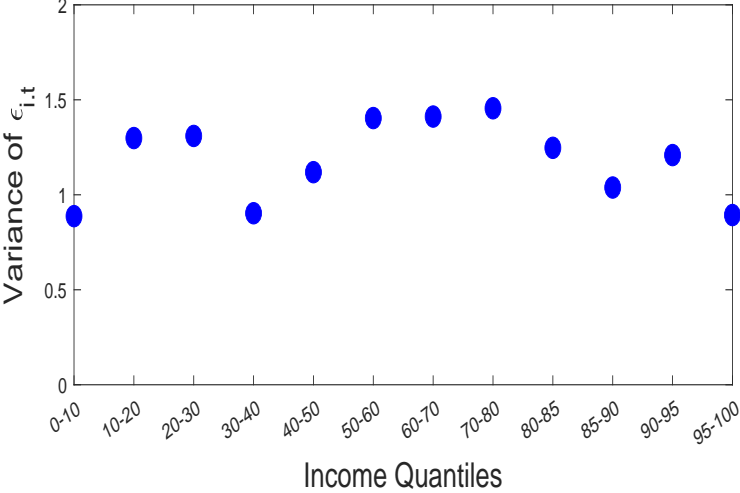
Panel B reports outcome that our quite similar to those reported in Table 5. This is perhaps not surprising because the interest rates in these two counterfactuals are close to each other.

Finally, Panel C shows that all reported statistics decrease in a market with a constant interest rate equal to the average reset rate, because interest rates increase for all borrowers.

We note that the model estimated separately for each income group reported in column (2) features a similar aggregate number of mortgages to the UK-wide case of column (1), which in combination with the results in Panel A suggests that allowing for heterogeneity between groups pushes toward slightly greater sensitivity to downward rate movements than upward rate movements.

H Additional Figures

Figure H.1: Variance of Refinancing Cost Shock across Groups



Notes: This figure displays the variance of the refinancing cost shock $\epsilon_{i,t}$ of households in each income group.