Mortgage Pricing and Monetary Policy*

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Abstract

Using the universe of U.K. mortgages originated during 2010-2014, we provide new evidence on lenders' mortgage pricing and how unconventional monetary policy may have affected it. Specifically, we show that lenders seek to segment the market by offering two-part tariffs composed of interest rates and origination fees, and that this two-part pricing has become more prevalent during recent periods of unconventional monetary policy, such as U.K.'s Funding for Lending Scheme. To understand the effects of lenders' pricing strategies on market equilibrium, we develop and estimate a structural model of mortgage choice and lender competition in which borrowers may have different elasticities to rates and fees. We use the estimated model to decompose the effect of unconventional monetary policy on mortgage pricing, as well as to compute the contribution of two-part pricing to lenders' profits and borrowers' surplus.

PRELIMINARY AND INCOMPLETE
COMMENTS WELCOME

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1 Introduction

Housing constitutes a main driver of business cycle dynamics and mortgage debt represents households' largest liability. In the aftermath of the Great Recession, governments and central banks around the world have sought to stimulate the economy through policies specifically designed to revamp the credit and housing markets. These include the various "credit easing" large asset purchase programmes, such as the Maturity Extension Programme and QE3 by the U.S. Federal Reserve, the Targeted Longer-term Refinancing Operations by the European Central Bank, and the Funding for Lending Scheme by the Bank of England, among others. A common goal of these unconventional monetary policies was to "enhance the functioning of the monetary policy transmission mechanism by supporting lending to the real economy" (ECB press release, 5 June 2014).

Stimulating the housing market via changes in credit conditions could be a powerful way to affect consumption and ultimately boost GDP. However, the literature as identified several frictions in the mortgage market that can impair the transmission of shocks and policies to the real economy. These include product design (Greenwald, 2018; Agarwal et al., 2017a,c), fixed versus adjustable rate contracts (Di Maggio et al., 2017; Garriga et al., 2017), household indebtedness (Cloyne et al., 2017; Baker, 2018), and market concentration (Scharfstein and Sunderam, 2016; Xiao, Forthcoming; Buchak et al., 2018a).

This paper explores a novel channel that can affect the transmission of unconventional monetary policy to the housing sector: price discrimination through two-part tariffs composed of origination fees and interest rates. The price-discrimination literature shows that menus of products with high-fees/low-rates and with low-fees/high-rates allow sellers to segment heterogeneous buyers and to extract surplus from them (Wilson, 1993). In mortgage markets, lenders may observe some of this heterogeneity, but perhaps they do not want to/cannot directly condition their prices on some observable characteristics—e.g., gender or income. However, if this heterogeneity leads borrowers to select different loan amounts, two-part pricing is an indirect tool to price this heterogeneity. For example, richer individuals may borrow larger amounts and, for large loans, high-fees/low-rates mortgages are cheaper than low-fees/high-rates mortgages.

We provide descriptive evidence on how lenders use this two-part pricing in the U.K.

mortgage market and how unconventional monetary policy may have affected their pricing strategy. Moreover, we develop and estimate a structural demand-and-supply model with rich borrower heterogeneity to quantify the effect of unconventional monetary policy on lending rates, the total cost of borrowing, and lenders' profits. Finally, we use the estimated model to compute the welfare costs and benefits of unconventional monetary policies across lenders and borrowers in the absence of this two-part pricing strategy.

Our analysis exploits the universe of mortgages in the UK in 2010-2014. These data allow us to provide new evidence on pricing strategies in the mortgage market and how lenders segment the market with different combinations of interest rates and origination fees. We document two main facts: (i) during our sample period, lenders increased the number of combinations of rates and fees for each product type, most notably by offering many mortgages with zero fees; and (ii) on average, lenders ask for a 30-basis-points higher interest rates on mortgage products with £1000-lower origination fees. Overall, these data patterns suggest that lenders are more-actively seeking to price discriminate across borrowers using two-part tariffs over time.

The descriptive evidence motivates us to understand how borrowers choose among rate-fee pairs, and how lenders pricing depends on their funding costs. To understand these issues, we develop and estimate a model of mortgage choice and lender competition. On the demand side, borrowers, who may have different elasticities to interest rates and origination fees, make a discrete choice of the optimal product and a continuous choice of the optimal loan amount. On the supply side, lenders offer differentiated mortgage products and maximize expected profits by setting interest rates and origination fees on their mortgage products, and by also choosing to borrow from the central bank facilities.

We identify the demand side using variation in product characteristics and borrower choices. We address endogeneity problem from the simultaneous nature of the discrete-continuous choice and from omitted variables correlated with the endogenous prices employing a two-steps procedure. In the first step, we estimate the joint likelihood of the discrete-continuous problem with a rich set of product-market fixed effects that allow us to fully account for selection and endogeneity in mortgage pricing. In the second step, we regress the estimated product-market fixed effects on exogenous product characteristics and instrument endogenous rates with cost-shifters. We identify the supply side parameters using variation

in product characteristics that affects marginal costs via default and interest-rate risks. Most notably, we exploit variation from the Bank of England Funding for Lending Scheme (FLS) to estimate the effect of unconventional monetary policy on lenders marginal costs. Participation to FLS is an endogenous choice by the banks, which can be correlated with potentially unobservable time-varying determinants of lenders marginal costs. Hence, we use an instrumental-variable strategy. First, we instrument average borrowing from FLS with the lenders' share of assets outside the U.K. before the FLS announcement interacted with an indicator variable equal to one in the post FLS period. The intuition for the instrument is that lenders' with a larger share of assets abroad benefit less from the FLS. Second, we instrument quarter-by-quarter borrowing from FLS with the fraction of assets held as cash in the same quarter. The idea of this instrument is that a large fraction of assets held as cash suggests that a bank may have few lending opportunities (i.e., face a lower demand) and, thus, it may not need additional FLS funds.

We find that borrowers are less elastic to fees than to rates. A one-percent increase in rates (fees) leads to a decrease of 0.24 (0.01) percent in loan demand. A one-percent increase in rates (fees) lead to a decrease of 5.8 (0.05) percent in product demand. To gauge a better sense of the relative magnitude we compute the decrease in fees that fully offsets a 10-basis-point increase in the interest rate in borrowers' demand functions. We find that a 10-basis-point-increase in the interest rate requires an average decrease of approximately £250 (£800) to keep the continuous loan (discrete product) demand constant. Thus, our structural "exchange-rate" between rates and fees straddle the reduced-form "exchange-rate" between rates and fees. On the supply side, we find that borrowing from the FLS facilities reduced lenders' funding costs by approximately 42-57 basis points.. Given an average marginal cost of about 230 basis points, the FLS decreases marginal costs by 18-25 percent for the average mortgage product.

The estimated structural model allows us to quantity the effects of the Funding for Lending Scheme on household borrowing costs and lenders' profits and how two-part pricing with rates and fees affect lenders' profits and borrowers' surplus. First, we study the equilibrium impact on the mortgage market of removing the effect of FLS on lenders funding cost. We find that on average the removal of the scheme increases marginal costs by 30 basis points, from 290 in the baseline case to 320 basis points. Both rates and fees increase,

by 28 basis points and 150 pounds, respectively. As a result of the increase of both rates and fees, average loan size and the number of mortgages originated decrease. Both lender profits and consumer surplus decline relative to the baseline case, as the increase in funding costs decreases overall market surplus. Lender profits decline by approximately three million per quarter, a decline of approximately six percent relative to baseline profits. Consumer surplus decline by less, one million only. Overall, the comparison between the changes in lender profits and in consumer surplus suggest that lenders appropriated most of the surplus increase due to lower funding costs during the FLS period.

Our second counterfactual case focuses on the effects of two-part pricing with rates and fees by considering a ban on origination fees.[1] Marginal costs changes minimally relative to baseline marginal costs, due to the reallocation of market shares to lower-funding-cost lenders. However, lenders increase interest rates on mortgage products by 27 basis points when origination fees are capped at zero. As a result of the higher rates, the average loan amount declines relative to the baseline by approximately £1,000 and similarly the number of mortgages originated declines as well. Both lender profits and consumer surplus decline relative to the baseline case. However, their decline is smaller than in the case of the removal of the FLS facilities reported in the second row. The reason for the decline in lender profits is simple: while lenders can increase interest rates to respond to the ban of origination fees, the increase in fee income does not fully offset the loss of fee income. The decline in consumer surplus is perhaps surprising, but it is due to the fact that borrowers are more elastic to interest rates than to origination fees and, thus, the increase in interest rates weighs more than the decline in origination fees in borrowers' utility functions.

Literature review. This paper aims to contribute to three, quite distinct strands of literature. First, the strand of research on estimating the effects of policies through credit markets and mortgages in particular. (Di Maggio et al., 2016; Greenwald, 2018; Agarwal et al., 2017a,c; Buchak et al., 2018a)

Second, the literature on mortgages design and, more generally, consumer financial products (Stanton and Wallace, 1998; Agarwal et al., 2017b; Crawford et al., 2018; Buchak et al., 2018b; Egan et al., 2017; Hastings et al., 2017; Koijen and Yogo, 2016).

[1]The Financial Conduct Authority (FCA) in the UK is currently considering the regulation of mortgage origination fees (*The Financial Times*, Mortgage lenders under FCA review for masking high fees, December 12, 2016).

Third, the literature on price discrimination (Miravete, 2002; Verboven, 2002; Agarwal et al., 2017c; McManus, 2007; Luo et al., 2018; Crawford et al., Forthcoming).

Overview. The remainder of the paper is organized as follows. Section 2 describes the data sources and provides motivating evidence and empirical facts in the UK mortgage market. Section 3 describes the Funding for Lending scheme and provides reduced-form evidence on the effects on the scheme on mortgage rates and fees. Section 4 develops the demand and supply model. Section 5 describes the estimation approach and the identification strategy. Section 6 describes the estimates from the counterfactual exercises. Section 7 concludes.

2 Data and Motivating Patterns

Our analysis combines different sources of data that we introduce in this Section. We begin by describing salient features of the supply side exploiting a rich dataset that reports the universe of contracts offered by all lenders in the U.K. mortgage market. We use these data to show how lenders use two-part pricing with interest rates and origination fees to segment the market. Finally, we present descriptive statistics on the choice sets of mortgage products over the sample that we will use in Section (5) to estimate our structural equilibrium model of the mortgage market.

2.1 Mortgage Products and Pricing

The first dataset that we exploit is the Moneyfacts Residential Mortgage Analyzer, which reports the near universe of mortgage products offered in the U.K. Moneyfacts is the U.K. leading provider of personal finance data through monthly coverage of the thousands of mortgage, savings, credit card, personal loan, business banking, life, pension and investment products offered by virtually every Bank and Building Society in the U.K. financial industry.

For each lender and mortgage product, we observe multiple characteristics, including loan-to-value (LTV) band, maximum advance and loan-to-income ratio, borrower type (i.e., first-time buyer, home-mover, or remortgager), rate type (i.e. fixed versus adjustable rate), fixed-term duration, maturity, initial interest rate and, crucial for our analysis, the origination

Table 1: Summary Statistics from Moneyfacts

	mean	sd	p50	min	max
Panel A: Products					
Products by month (#)	2560.66	484.61	2531.00	1538.00	3558.00
Product types by month (#)	919.17	124.42	924.00	642.00	1117.00
Products by type/month (#)	2.79	2.48	2.00	1.00	24.00
Lenders by month (#)	18.17	0.59	18.00	17.00	19.00
Products by lender/month (#)	140.93	104.95	114.00	10.00	720.00
Product types by lender/month (#)	50.59	15.65	50.00	6.00	87.00
Panel B: Prices					
Rate (%)	3.85	1.08	3.74	1.49	6.99
Fee (£)	702.33	551.84	875.00	0.00	2999.00

Note: Summary statistics of the main variables used in the analysis. Sample: 2010-2014. Source: Moneyfacts Residential Mortgage Analyzer.

fee. We define a product type as a combination of three features: (i) interest rate type with fixation period; (ii) lender; and (iii) maximum loan-to-value ratio. This definition builds on the fact that U.K. mortgage pricing depends essentially on two key variables: the loan-to-value, which captures default risk, and the fixation period, which captures interest rate risk (Best et al., 2018; Benetton, 2018).[2] We define a product as the combination of a product type and a pair of associated rate/fees.

Table 1 illustrates the richness of this dataset. Panel A reports the number of total products and product types, per month and per lender. Panel B reports initial rates and origination fees. The first two columns report average values and standard deviations, the next three columns report median, minimum, and maximum values.

The first row of Panel A reveals that, in a typical month, there are more than 2,500 residential mortgage products on offer in the U.K. The second row reports that the number of product types per month exceeds 900. We remind that we define a product as the combination of a product type and a pair of associated interest rate/origination fee; the third row reveals that the typical product type exhibits an average of 2.79 multiple fee/rate quotes—e.g., a high-fee/low-rate product, a medium-fee/medium-rate product, and a low-fee/high-rate product. Figure 1, taken by website of a major lender, displays a typical example of a lender offering the same product type—i.e., identical fixed term, maximum

[2] A regression of the loan-level rate on interacted product type-month fixed effects and the corresponding fee explain more than 90 percent of the variation.

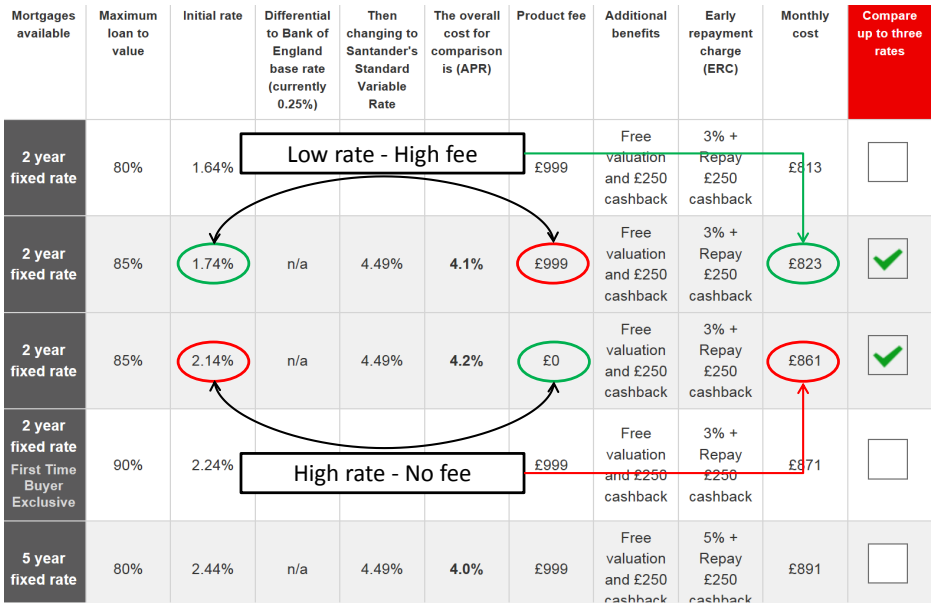


Figure 1: Product Definition

Note: Snapshot from the website of a large lender on offered mortgages with a fixed initial rate period of two years.

LTV, additional benefits and early repayment charges—at two distinct fee/rate quotes. The fourth row reports the number of lenders, which is very stable over our sample, between 17 and 19, with a typical lender offering an average of about 140 products (fifth row) and around 50 product types (sixth row) per month. Finally, the two rows of Panel B describe the large variation in rates and fees. More specifically, the initial interest rates associated with the products in Panel A vary from about 1.5 percent to 7 percent, with an average of 3.85 percent, whereas the origination fees vary from zero to £2,099, with an average cost of approximately £700.

Figure 2 displays the share of products with a unique fee/rate quote and the share of products with zero fees over the period 2010-2014, uncovering two main trends. First, the share of product types offered with a unique quote has halved over our sample period, declining from more than 15 percent in 2010 to approximately seven percent in 2014. Second, the share of multi-quote products offered with zero fees has more than doubled, steadily increasing from ten percent of the market in 2010 to almost 25 percent in 2014. The growing importance of products with multiple rate-fee pairs documented in Figure 2 suggests that

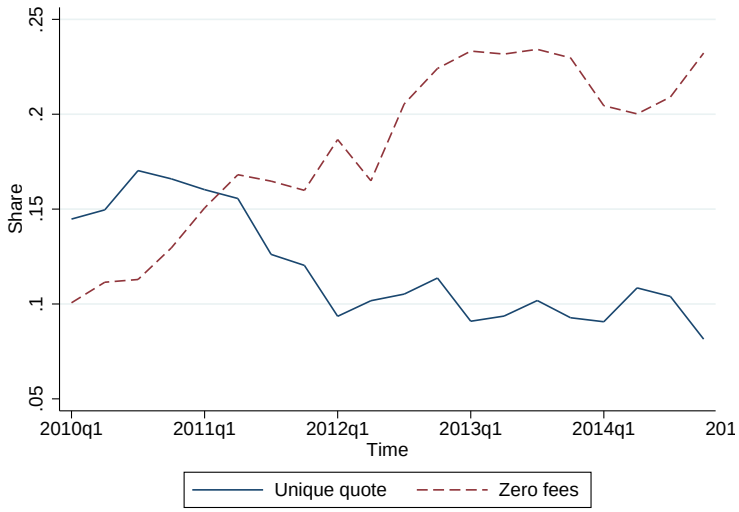


Figure 2: Product Shares

Note: share of products in Moneyfacts with a zero fee and the share of products with a unique quote.

lenders are more-actively seeking to price discriminate across borrowers using a two-part pricing strategy over time. This seems a novel aspect of mortgage pricing to study, for at least two reasons. First, the vast majority of previous studies on mortgage markets has focused on the interest rate that borrowers pay when taking a mortgage. However, origination fees can represent an important component of the total cost of borrowing, most notably since refinancing is frequent in the U.K. market (Cloyne et al., 2018) and, thus, borrowers may end up paying the origination fee frequently. Looking only at the interest rate may provide an incomplete picture of the mortgage costs for borrowers (as well as of profits for lenders) and, thus, of the transmission mechanism of monetary policy. Second, if borrowers have different elasticities with respect to rates and to fees, lenders can set them strategically and further increase their profits.

We now describe the variation in rates and fees across product types with different LTV bands, as well as the correlation between rates and fees. Specifically, in the panels of Figure 3, we display how initial interest rates (left chart) and origination fees (right chart) vary across maximum LTV bands. Two main patterns emerge. First, there are notable jumps across max LTV bands, especially above 80 percent. This suggest that U.K. lenders seem to price default risk almost exclusively through LTV bands, and not through borrower-specific pricing, as it is instead the case in the U.S. mortgage market. This feature of the U.K.

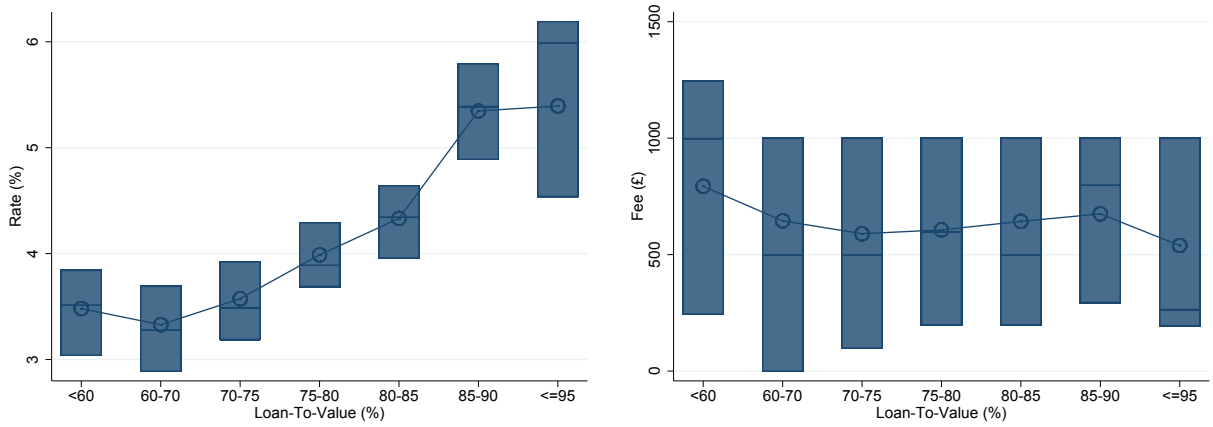


Figure 3: LTV PRICING

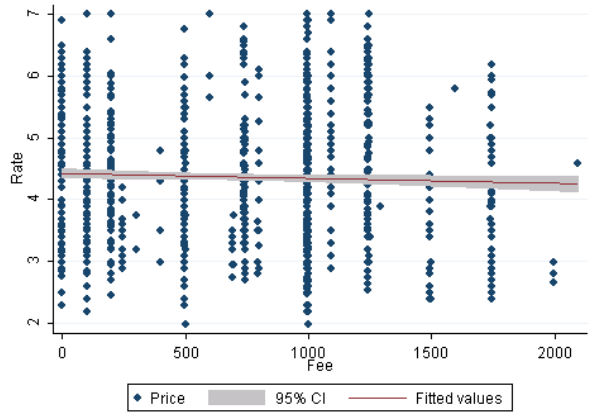
Note: The left (right) Panel shows the interquartile range for initial interest rates (origination fees) for all products in each LTV band based on the Moneyfacts dataset.

mortgage market motivates us to model borrowers' choice as a discrete-choice among these LTV bands, lenders, and other product characteristics. Second, and in sharp contrast to interest rates, origination fees exhibit very limited variation across LTV bands, potentially suggesting that lenders use them mainly to extract consumer surplus. We will explore this hypothesis below, through the lens of an estimated structural model of the U.K. mortgage market in which borrowers are allowed to have different elasticities to interest rates and to origination fees.[3]

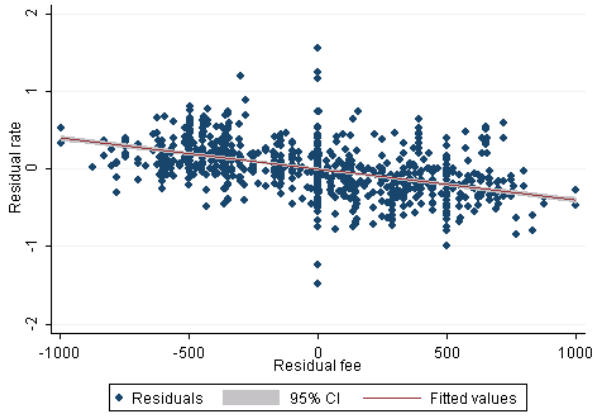
In Figure 4, we present the correlation between initial interest rates and origination fees. The left panels displays rates and corresponding fees for all mortgage products in the first (December 2010), middle (December 2012) and last month (December 2014) of our sample. Rates are continuous, while fees often take on discrete values at (almost) round numbers, such as zero, 499-500, 999-1000, and 1250. A negative correlation between rates and fees seems apparent, perhaps more so in 2012 and in 2014 than in 2010. The right panels of Figure 4 display the residual rates and the corresponding residual fees obtained from regressing the product-level rates and fees, respectively, on product type-month fixed effects. The negative correlation between rates and fees becomes sharper within product-type, consistent with the example of Figure 1.

To quantify more formally the magnitude of the negative relation between rates and fees,

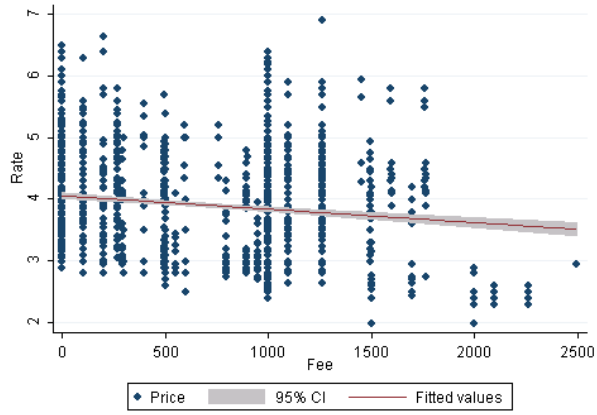
[3]In Figure A1 in Appendix A, we replicate the charts of Figure 3 using data on mortgage *originations* obtained from the Financial Conduct Authority's Product Sales Database.



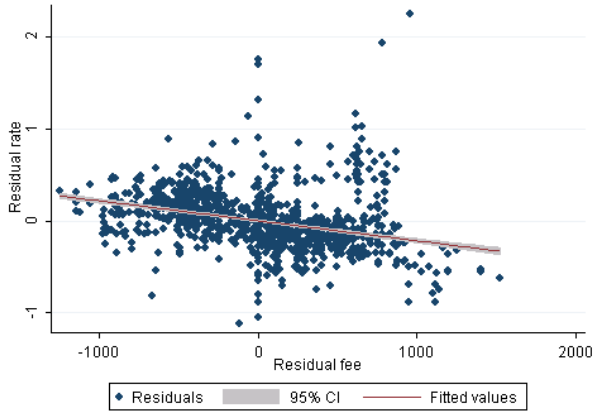
(a) Raw data, December 2010



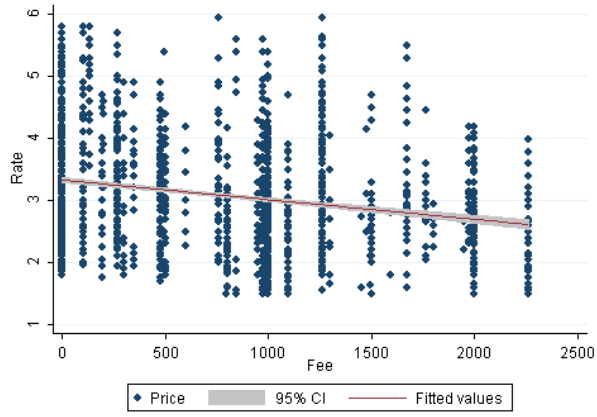
(b) Residuals, December 2010



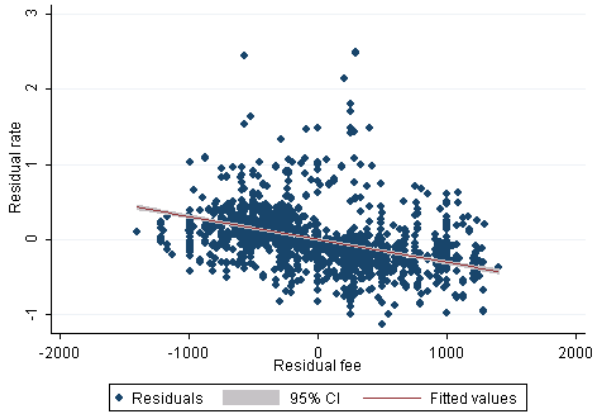
(c) Raw Data, December 2012



(d) Residuals, December 2012



(e) Raw Data, December 2014



(f) Residuals, December 2014

Figure 4: Relation between Rates and Fees

Note: Panels (a), (c) and (e) show the correlation between rates and fees in December 2010, 2012, and 2014 respectively. Panels (b), (d) and (f) show the correlation between the residual rates and fees in December 2010, 2012 and 2014 respectively. The residuals are computed regressing the product-level rates and fees on product type-month fixed effects.

Table 2: Relation Rates-Fees

Panel A: Continuous Fees

	Baseline	Heterogeneity								
		(Fix)	(Var)	(<75)	(>75)	(Big 6)	(Other)	(FTB)	(HM)	(RMGT)
Fee (.000)	-0.281***	-0.297***	-0.228***	-0.279***	-0.296***	-0.283***	-0.279***	-0.274***	-0.288***	-0.280***
	(0.011)	(0.011)	(0.023)	(0.012)	(0.016)	(0.015)	(0.014)	(0.016)	(0.015)	(0.015)
Product-Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.94	0.95	0.90	0.92	0.95	0.95	0.93	0.95	0.94	0.93
Observations	158648	115662	42986	137358	21290	68790	89858	55611	53734	49303

Panel B: Zero-fee Indicator Variable

	Baseline	Heterogeneity								
		(Fix)	(Var)	(<75)	(>75)	(Big 6)	(Other)	(FTB)	(HM)	(RMGT)
Zero fees	0.332***	0.337***	0.315***	0.338***	0.285***	0.349***	0.321***	0.328***	0.339***	0.329***
	(0.012)	(0.013)	(0.020)	(0.013)	(0.019)	(0.012)	(0.017)	(0.016)	(0.016)	(0.015)
Product-Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.93	0.94	0.90	0.91	0.94	0.95	0.92	0.94	0.93	0.93
Observations	158648	115662	42986	137358	21290	68790	89858	55611	53734	49303

Note: Panel A reports the estimates from equation (1) using as explanatory continuous variable the level of fees. Panel B reports the estimates from equation (1) using as explanatory indicator variable a dummy for products with zero fees. Standard errors are double clustered at the product and time level. Source: MoneyFacts dataset.

we run the following regression on MoneyFacts data:

$$r_{jkt} = \alpha f_{jkt} + \gamma_{kt} + \epsilon_{jkt}, \tag{1}$$

where r_{jkt} is the interest rate of product j, product-type k at time t, f_{jkt} is the corresponding fee, γ_{kt} are product type-time fixed effects, and ϵ_{jkt} are unobservables. The coefficient of interest is α, which measures the within product type-time rate of substitution between initial interest rates and origination fees. We estimate two specifications of (1): one with the fees in level as a continuous variable; another one with an indicator variable equal to one for products with no fees and zero otherwise.

We report the coefficient estimates in Table 2. In Panel A, we show the baseline model with continuous fees. The first column shows that a £1,000-higher origination fee corresponds to a 28-basis-point-lower interest rate within product type. The other columns report coefficients obtained on different subsamples of the data, e.g. for different product types (depending on the interest rate type, maximum loan-to-value, lender) and for different borrower types (first-time buyer, home mover, and remortgager). The result is remarkably stable across subsamples. In Panel B of Table 2, we report the coefficient estimates of

equation (1) when we use as explanatory variable an indicator variable equal to one for products with no fees and zero otherwise. The estimates imply that a product with zero fees tends to be offered at an interest rate that is on average 33 basis point higher than an identical product type but with a positive fee. All estimates on different subsamples show very limited hetereogeneity.

In summary, we uncover two main patterns: (i) lenders have increased over time their offer of product types with multiple rate-fee combinations, presumably in an attempt to segment the market and to price discriminate across borrowers using two-part quotes; and (ii) lenders charge approximately a 30-basis-point-higher rate on a mortgage with a £1000-lower origination fee, with almost no heterogeneity across product types.

2.2 Mortgage Choice

The second dataset that we exploit is the Product Sales Database (henceforth PSD) constructed by the Financial Conduct Authority (henceforth FCA). PSD collects all mortgage originations, reporting mortgage contract characteristics: the interest rate, the LTV, the maturity, the loan amount, the lender; the main borrower characteristics: age, income, and borrower type (first-time-buyer, home-mover, remortgager); and property characteristics: the location and transaction price.

Despite the richness of the PSD, it has two limitations for our purposes. First, it reports mortgage fees only since 2015, which is after the introduction of the Bank of England's Funding for Lending Scheme in 2012. We overcome this limitation since PSD reports the main characteristics of each origination, such as the lender, the LTV, and the interest rate, which allow us to match each PSD mortgage to the corresponding mortgage product from MoneyFacts to recover its origination fees. Second, PSD does not report borrowers' choice sets—for example, some mortgage products may be unavailable to some borrowers. We address this issue by exploiting the choice of borrowers with similar observable characteristics to construct the choice set of each borrower depending on his age, income, region, and quarter. Most notably, we divide borrowers into groups based on the region they bought the house, the quarter in which they obtain the mortgage, and on their income and age (below vs above the median). We assume that a borrower has access to the mortgage products that other borrowers in the same group have chosen. Moreover, to account for differences among

borrowers within the same group in unobservable characteristics, such a wealth, we restrict the discrete loan-to-value band choice to the maximum loan-to-value bands just above and just below the band which the chosen product falls into. This additional restriction removes products that were unlikely to belong to borrowers' choice sets because of leverage limits, such as loan-to-income or loan-to-value constraints.

Table 3 reports summary statistics for the 2010-2014 dataset that we use to estimate our model. We focus on first-time-buyers for two main reasons. First, home movers' and remortgagers' *new* mortgage choice is affected by their *existing* mortgages, which we do not observe in our datasets. Second, first-time-buyers are the borrowers with the highest leverage, which makes them potentially more responsive to the monetary stimulus that we focus on in this paper. The estimation sample comprises of approximately 728,000 mortgages, and Panel A reports their main characteristics. The average loan has an amount of about £135K and a maturity of approximately 28 years. The average loan amount on adjustable-rate products is significantly larger than that on fixed-rate products. The average borrower is less than 30 years old and has an income of about £42K (£59K for products with variable rates). The average LTV is about 82 percent and the average loan-to-income is 3.4.

Panel B of Table 3 reports some additional statistics on borrowers' choice sets. Each choice set (namely the combination of product type and a pair of associated rate/fees) features approximately 50 product types and approximately 70 products—i.e., we observe two different rate/fee combinations for approximately 40 percent of product types. The average initial rate in equals 420 basis points, with adjustable rate deals typically offered at 60 basis points less than fixed rate ones. Products with a maximum LTV above 75 percent feature considerably higher interest rates than products with lower maximum LTVs, as Figure 3 displays. Average origination fees amount to approximately £660, though they are slightly lower for products with maximum LTV above 75 percent.

Overall, Table 3 exhibits a large heterogeneity in borrowers' choices, suggesting a large heterogeneity in borrowers' preferences. This heterogeneity also accounts for borrowers' choices between high-fee and low-fee products, as theory predicts. For example, the left panel of Figure 5 shows that the fraction of borrowers choosing no-fee products declines as borrowers' loan amounts increase. This is consistent with the choice of the product with lower NPV (or net present cost). The right panel of Figure 5 shows the difference in NPV between

Table 3: Summary Statistics

	All	Rate		LTV		Lender	
		Fix	Var	Low	High	Big 6	Others
Panel A: Choices							
Loan amount (£, 000)	134.78	131.08	174.47	137.75	128.92	133.81	161.23
Maturity (years)	28.85	29.05	26.73	28.30	29.93	28.85	28.74
Gross income (£, 000)	41.55	39.94	58.82	42.04	40.59	41.12	53.22
Age (years)	30.08	29.90	32.00	30.51	29.23	30.08	30.00
Loan-to-value	82.42	82.60	80.51	78.66	89.86	82.41	82.84
Loan-to-income	3.45	3.47	3.24	3.52	3.31	3.46	3.22
Initial rate (%)	4.31	4.36	3.68	3.86	5.16	4.31	4.04
Fees (£) (%)	723.60	740.15	545.94	762.02	647.75	726.49	645.39
Panel B: Choice-set							
Initial rate (%)	4.20	4.36	3.71	3.85	5.09	4.22	4.07
Fees (£) (%)	661.72	664.68	652.22	702.04	560.69	656.39	719.53
Product type identifier	55.27	42.31	12.99	39.80	15.47	51.34	4.11
Product identifier	62.57	47.72	14.89	44.72	17.85	57.29	5.53

Note: Summary statistics for the main variables used in the analysis.

the high-fee (low-rate) and the low-fee (high-rate) products for different loan amounts. For borrowers with small loan amounts the high-free product has a higher NPV. The latter declines with the quantity and for borrowers with quantities above £300 thousands the high-fee products becomes a better option in NPV terms. Thus, the model that we develop in Section 4 will feature rich observable and unobservable borrower heterogeneity to capture their choice of mortgage product from lenders' menus. Figure 5 shows the importance of observable heterogeneity, such as the quantity choice. Figure 6 shows the importance of unobservable heterogeneity. For each borrower in the sample who chooses a mortgage type with more than one pair of fees and rates we compute the NPVs for the different combination of fees and rates. We find that around 40 percent of borrower do not choose the mortgage that minimize the net present value and this fraction is stable across different loan amounts. Figure 5 also shows the differences in pounds among the chosen option and the cheapest available option given the quantity chosen. Choosing the relative more expensive option generate higher cost by about £800-1,200. We do not explore the micro-foundations for these sub-optimal choices which can arises from unobservable constraints, consumers mistakes and behavioural biases, but we allow for rich unobservable heterogeneity across individuals and products in the model.

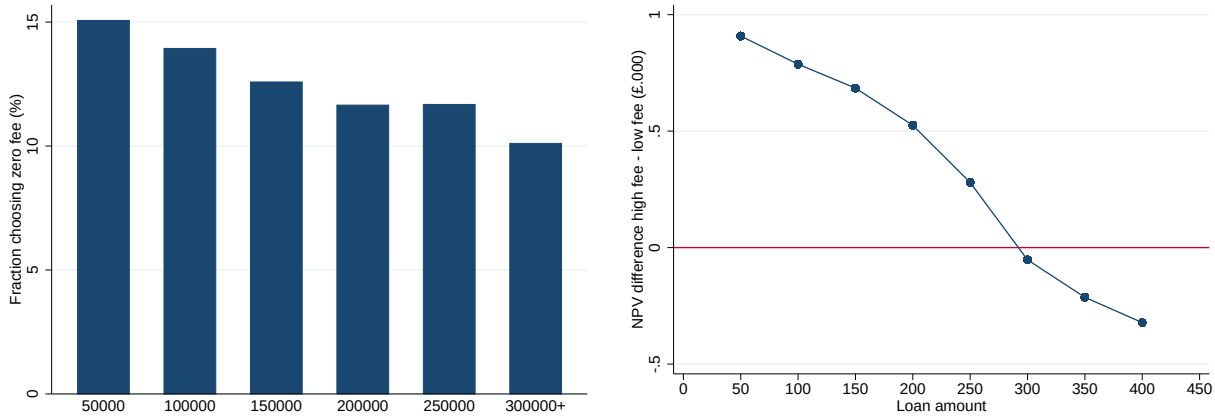


Figure 5: Fee choice as function of quantity

Note: The left panel shows the fraction of borrowers choosing no-fee products for different loan size bands. The right panel shows the net-present-value (NPV) difference between the high-fee (low-rate) and the low-fee (high-rate) mortgage option for different loan size bands.

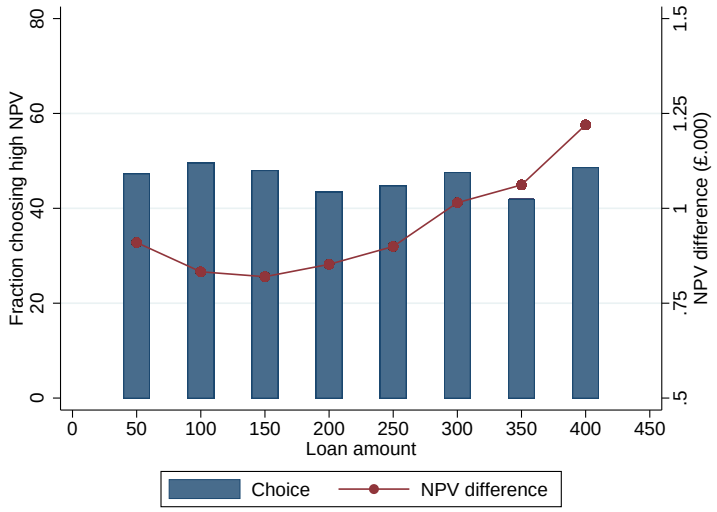


Figure 6: Net present value choice as function of quantity

Note: The figure shows the fraction of borrowers choosing the product with the highest net-present-value (NPV) for different loan size bands and the difference in NPV. For each borrower in the sample who chooses a mortgage type with more than one pair of fees and rates we compute the NPVs for the different combination of fees and rates. We compute the NPV without discounting focusing on the fix period of the contract (usually two or five years). The red line shows the differences among the chosen option and the cheapest available option given the quantity chosen.

3 The Funding For Lending Scheme

A main goal of our analysis is to study how mortgage pricing, especially origination fees, affects the transmission of monetary policy. While this question is also relevant for conventional interest rate policies, it is particular salient for the large number of unconventional interventions that dominated the responses of central banks around the world to the financial crisis and that has been popularized under the heading of 'credit easing'. A case in point is the U.K. Funding for Lending Scheme (henceforth FLS), whose main features and impact on mortgage pricing we describe in this section.

3.1 Institutional Background and Lenders' Funding Costs

On June 14th, 2012, Governor Mervyn King announced the introduction of the Bank of England and HM Treasury FLS programme, which officially started on July 13th, 2012. The scheme was part of the larger monetary stimulus package that the Bank of England pursued since the onset of the Financial Crisis, along the lines of similar programs by other central banks (Borio and Zabai, 2016).[4]

The timing of FLS followed an intensification of the European Sovereign Debt Crisis and an increase in banks' funding costs for the major UK lenders, which in turn led to an increase in loan rates. Figure 7 displays funding costs for the six (anonymized) largest U.K. lenders.[5] Black vertical lines denote key banking events, whereas the red vertical line marks the announcement of the FLS. The time series of these funding costs display two large increases: one during the Great Recession in 2007-09 and one during the intensification of the European Sovereign Debt Crisis in 2011-2012. After the FLS announcement, lenders' funding spreads decreased considerably; by the second half of 2013, the level and dispersion of the funding spreads were close to those prevailing before the financial crisis.

The FLS programme provides direct funding to banks and building societies for an extended period at lower rates than prevailing on the market, with the stated goal of

[4]The Bank of England cut interest rate to 0.5 percent in March 2009 and from September 2009 to July 2012 purchased a total of £375 billion in assets, mainly U.K. government securities, but also smaller quantities of high-quality corporate bonds.

[5]More formally, Figure 7 reports the constant maturity secondary market spreads to mid-swaps for the largest U.K. lenders' five-year euro-denominated senior unsecured bonds (or a suitable proxy when unavailable) as constructed in the Bank of England Credit Conditions Review 2017Q3 (chapter 1, chart 1.2).

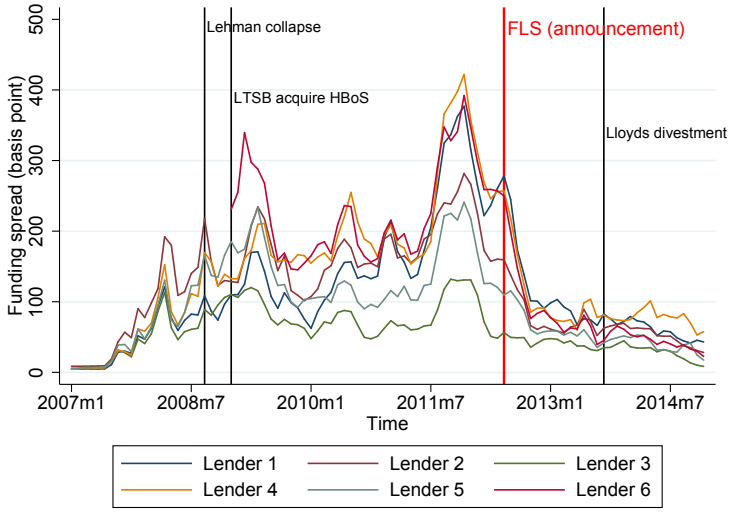


Figure 7: Funding costs

Source: Bank of England.

promoting lending to households and firms. The scheme incentives operate through both quantities and prices. As for quantities, the amount of funding available varies with the amount that banks lend out as follows. First, each lender can borrow from the Bank of England up to five percent of its existing stock of loans to households and to firms at June 2012. Second, banks can borrow beyond this five percent limit as long as the additional borrowing leads to a net expansion (i.e. net of repayments) of their lending to households and firms over the period July 2012-December 2013. In other words, banks can finance each pound of new lending with a pound from the FLS, facing no constraint on the additional amount that they can borrow for this purpose. As for the scheme incentive on prices, the funding cost depends on the amount that banks lend out. Banks that maintain or expand lending pay an annual fee of 25 basis points for the amount that they borrow from the FLS facilities. Banks that reduce net lending pay an additional fee of 25 basis points for each percentage point of decline in net lending. This fee increases linearly up to a maximum of 150 basis points for banks that reduce net lending by more than five percent.

By the end of 2014, the FLS recorded an aggregate outstanding drawings of more than £4.4 billions, with an associated increase in aggregate lending of about 2.5 percent. All large lenders, with the notable exception of HSBC, participated in the FLS. The scope of the scheme narrowed over time and since February 2014 excluded household loans such

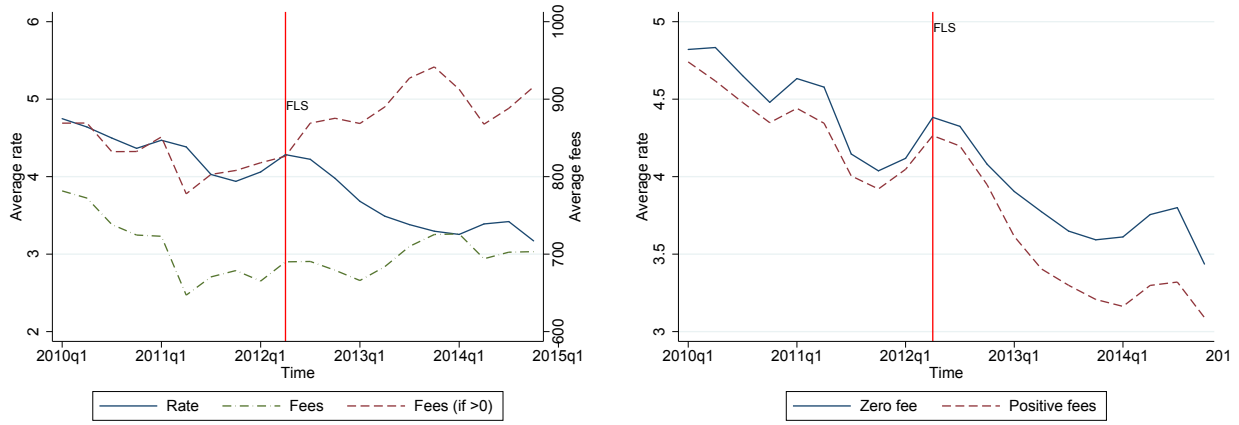
as mortgages, amid rising property values. After that, FLS supported loans to small and medium-sized enterprises only. Churm et al. (2012) provides a more-detailed description of the FLS, as well as some evidence on the short-term effects of the scheme on the interest rates that lenders charged to firms and to households.

3.2 Mortgage Pricing around the FLS

We now describe some notable changes in mortgage pricing around the introduction of the FLS programme. Panel (a) of Figure 8 displays the evolution of the average rates (left axis), the average fees for all products and the average fees for only products with positive fees (right axis). Panel (b) displays the average rates for products with positive fees and for products with zero fees. The vertical line denotes the FLS announcement.

The evidence in Panel (a) suggests that the decline of mortgage rates (blue solid line), which was already ongoing before July 2012, perhaps accelerated after the introduction of the scheme. The average mortgage rate decreased by almost 100 basis points, from approximately 420 points in the second quarter of 2012 to 320 points by the end of 2013. This finding is consistent with lenders passing through their lower funding cost to lower mortgage rates. Average fees display a similar trend to average interest rates before the introduction of FLS, but seem to diverge thereafter. Origination fees do not display a noticeable average change after the introduction of FLS and, if anything, they reveal a gentle increase from below £700 to just above it. However, if we consider only products with strictly positive fees (red dashed line), their average fees increase more markedly after the introduction of FLS, by approximately £100. These patterns lend support to the hypothesis that, in response to the FLS, lenders may have adjusted interest rates downward to attract borrowers, while increasing origination fees for some of their products, possibly to extract consumer surplus and to increase profits.

In Panel (b) of Figure 8, we investigate this hypothesis further by decomposing the decline in the average rate displayed in Panel (a) between products with positive fees (red dashed line) and products with zero fees (blue solid line). Before the introduction of the FLS, the two rates display a parallel trend, with the no-fee products associated with a higher rate than the positive-fee products, consistent with the evidence reported in Section 2. However, after the beginning of the FLS programme, the gap between the two rates widens: the decline in



(a) Rates and fees (b) Rates at different fee levels

Figure 8: FLS and Mortgage Pricing

Note: The left panel displays the average interest rate, the average fee, and the average fee conditional on the fee of the product begin larger than zero. The lower panel shows the average interest rate for product with positive fees and for product with zero fees.

interest rates is substantially smaller for no-fee products than for positive fee ones, with the difference in rates between the two set of products moving from an average of about 10 basis point in 2012Q2 to an average of around 50 basis points by 2014.

4 A Structural Model of the Mortgage Market

The descriptive evidence of previous sections reports some intriguing pricing patterns. At the same time, it raises several interesting questions. Specifically, how do borrowers choose among rate-fee pairs? How does FLS affect lenders' funding costs? How do lenders pricing depends on their costs, as well as borrowers' demand? What was the effect of FLS on market equilibrium?

The goal of the model that we develop in this section, as well as of the counterfactual analyses of Section 6, is to allow us to answer these questions in a coherent way.

4.1 Households Mortgage Demand

In each market m and quarter t, I_{mt} heterogeneous borrowers, indexed by i, choose a mortgage to buy a house. We define a market m as a combination of geographic region (six regions in total) and demographic characteristics (four categories based on income and age, below and above their respective medians), yielding a total of 24 markets.

Borrowers choose simultaneously their mortgage product among all lenders, rate types, and maximum loan-to-values available to them (discrete product choice), as well as their loan amount, given their preferences and budget constraint (continuous quantity choice). We assume that each mortgage is represented as a bundle of attributes and that borrowers have preferences over these attributes. The indirect utility for borrower i taking product j in market m in quarter t is:

$$V_{ijmt} = \bar{V}_{ijmt}(Y_i, D_i, X_j, r_{jmt}, f_{jmt}, A_{ij(l)mt}, \zeta_i, \xi_{jmt}; \theta_m) + \varepsilon_{ijmt}, \tag{2}$$

where Y_i is household income; D_i are other household demographics (e.g., age, location); r_{jmt} is the rate and f_{jmt} is the origination fee of product j in market m in quarter t; X_j are time invariant product type characteristics (i.e., rate type, lender and maximum loan-to-value); $A_{ij(l)mt}$ is lender l's branch network in the location of household i; ζ_i captures borrowers' unobserved characteristics (e.g., wealth, risk-aversion, housing preferences); ξ_{jmt} captures unobservable product characteristics (e.g., advertising, screening) affecting the utility of all borrowers for product j in market m and period t; ε_{ijmt} is an idiosyncratic taste shock; and θ_m collects the demand parameters common to all borrowers in market m.

Following Benetton (2018), we construct the choice set of each borrower by comparing other borrowers with similar observable characteristics and imposing two additional restrictions based on affordability and liquidity constraints. First, borrowers may not be able to borrow up to the desired leverage, due to restrictions, such as loan-to-value or loan-to-income limits. Second, liquidity constraints may limit the ability of the borrower to increase the down-payment and consider products with lower maximum leverage. Both types of constraints restrict borrowers' choice sets in terms of maximum loan-to-value accessible among the full set available in the market. We assume household i solve the following problem:

$$\begin{aligned}
&\max_{j \in J_i} V_{ijmt} = \bar{V}_{ijmt} + \varepsilon_{ijmt}, \\
&\quad with\ J_i \subseteq J_{mt} \quad Affordability\ constraint \\
&\qquad j \in J_i\ if\ j \in \{max\ LTV_i - 1, max\ LTV_i, max\ LTV_i + 1\},
\end{aligned}$$

where J_{mt} is the total number of products available in a market m and quarter t. In the

standard case, all borrowers can choose from the full set of products, thus $J_i \equiv J_{mt}$.

Borrower i chooses the product that gives her the highest utility, among the products available, that is i chooses product j if $V_{ijmt} \geq V_{ij'mt}, \ \forall j' \in J_i$. Hence, the probability that borrower i chooses product j in market m and quarter t given the value of his unobserved heterogeneity ζ_i equals:

$$p_{ijmt}(\zeta_i) = Prob(V_{ijmt} \geq V_{ij'mt}, \ \forall j' \in J_i). \tag{3}$$

At the chosen product, the borrower decides the optimal loan amount q_{ijmt}, which follows from Roy's identity:

$$q_{ijmt} = -\frac{\frac{\partial V_{ijmt}}{\partial r_{jmt}}}{\frac{\partial V_{ijmt}}{\partial Y_i}} = q_{ijmt}(Y_i, D_i, X_j, r_{jmt}, f_{jmt}, \zeta_i, \xi_{jmt}; \theta_i). \tag{4}$$

Equations (3) and (4) uniquely define borrowers' product and loan demand, respectively, given their preferences and mortgage characteristics. In practice, our assumptions imply one exclusion restriction: the quantity choice does not depend on lenders' network of branches. This characteristic affects the probability of choosing a specific mortgage products—equation (3)—but not the optimal loan amount—equation (4).

4.2 Lenders' Revenues, Costs, and Pricing

L_{mt} lenders maximize (expected) profits by pricing the mortgage products that they offer in market m and quarter t, given their funding costs, which depend on lenders' use of the FLS facilities once they become available.

Revenues. The vast majority of UK mortgages have a discounted variable or fixed rate, which revert to a higher standard variable rate at the end of the fixation period. Hence, borrowers have strong incentives to refinance the mortgage with a new loan when the fixation period terminates (Cloyne et al., 2018). We focus on revenues and pricing at origination, and leave to future research the analysis of retention pricing. Hence, lenders' main revenues are the net interest income from the monthly payments and the initial origination fee.

Given the demand system and borrowers' refinancing after the initial fixation period, the

flow of lender l's expected total revenues in quarter t equal:

$$TR_{lt}(r_{jmt}, f_{jmt}) = \sum_{m} \sum_{j \in J_{lm}} \sum_{i \in I_{mt}} s_{ijmt}(r_{jmt}, f_{jmt}, r_{-jmt}, f_{-jmt}) \left(\frac{f_{jmt}}{\tau_{jmt}} + q_{ijmt} r_{jmt} \right), \qquad (5)$$

where τ_{jmt} is the length of product j's fixation period. Thus, lenders' expected revenues in quarter t are the sum of revenues collected across markets m ($\sum_m$) from all products j offered ($\sum_{j \in J_{lm}}$) to borrowers in each market ($\sum_{i \in I_{mt}}$). Given borrowers' refinancing at the end of the fixation period τ_{jmt}, the revenue function (5) accounts for the fact that products with a shorter fixation period generate higher flow profits from fees f_{jmt}. Moreover, note that the rates of other products and fees enter into the discrete product demand $s_{ijmt}(\cdot)$, but not into the continuous conditional loan demand q_{ijmt}.

Costs and FLS. Lenders face two types of costs of their mortgage business: 1) a fixed cost a_{jmt} for each mortgage that they issue, thereby capturing, among others, administrative costs of processing mortgage applications; and 2) variable costs, which depend on their total amount of mortgage lending in quarter t.

In turn, these variable costs include: 2.A) Total costs $FC_{lt}(A_{lt})$ of funding lenders' total assets A_{lt}, which include their mortgages $Q_{lt} = \sum_m \sum_{j \in J_{lm}} \sum_{i \in I_{mt}} q_{ijmt}$ issued in quarter t. We assume that $FC_{lt}(A_{lt})$ is an increasing function of A_{lt}. 2.B) Additional costs specific to mortgage product j in quarter t, such as capital requirements, or costs to cover any interest rate risk deriving from the maturity mismatch between lenders' liabilities and the specific mortgage product. We assume that these additional costs equal $c^o_{jt} \sum_m \sum_{i \in I_{mt}} q_{ijmt}$.

Aggregating different costs, lenders' total flow costs in the mortgage market in quarter t equal:

$$TC_{lt}\left(q_{i1}, ..., q_{iJ_{lt}}\right) = \sum_{m} \sum_{j \in J_{lm}} \sum_{i \in I_{mt}} s_{ijmt} \frac{a_{jmt}}{\tau_{jmt}} + FC_{lt}(A_{lt}) + \sum_{j \in J_{lt}} c^o_{jt} \sum_{m} \sum_{i \in I_{mt}} q_{ijmt}, \qquad (6)$$

where J_{lt} denotes all products that lender l offers in quarter t, and we adjust the application costs for the fixation periods τ_{jmt} as we did in the case of origination fees f_{jmt}.

Hence, the marginal cost mc_{jt} of lending an additional pound sterling on mortgage

product j equals:

$$mc_{jt} = c^o_{jt} + \frac{\partial FC_{lt}(A_{lt})}{\partial q_{ijmt}}. \tag{7}$$

The introduction of FLS potentially changes lenders' costs, as they can access the FLS facilities. We model this new funding option as follows: Each lender l can chooses how much to borrow $Q_{FLS,lt}$ in each quarter t in order to minimize funding costs, subject to the FLS rules. Formally, each lender solves:

$$\min_{Q_{FLS,lt}} FC_{lt}(A_{lt} - Q_{FLS,lt}) + p_{FLS,lt}Q_{FLS,lt}$$
$$\text{subject to: } Q_{FLS,lt} \leq Q_{\overline{FLS},lt},$$

where $p_{FLS,lt}$ is cost of borrowing from the FLS facilities and $Q_{\overline{FLS},lt}$ is lender l's allowance. The optimality condition for $Q_{FLS,lt}$ implies that marginal costs satisfy:

$$mc_{jt} - c^o_{jt} = \begin{cases} \frac{\partial FC_{lt}(A_{lt})}{\partial q_{ijmt}} \leq p_{FLS,lt} & \text{if } Q_{FLS,lt} = 0, \\ p_{FLS,lt} & \text{if } 0 < Q_{FLS,lt} < Q_{\overline{FLS},lt}, \\ \frac{\partial FC_{lt}(A_{lt} - Q_{\overline{FLS},lt})}{\partial q_{ijmt}} \geq p_{FLS,lt} & \text{if } Q_{FLS,lt} = Q_{\overline{FLS},lt}. \end{cases} \tag{8}$$

Equation (8) illustrates that the marginal funding cost of those lenders not borrowing from the FLS facilities should be lower than the cost of FLS funds (which equals $p_{FLS,lt}$), that of those lenders borrowing less than their total allowance should equal the cost of FLS funds, and that of those lenders borrowing all their total allowance should be higher than the cost of FLS funds.

Mortgage Pricing. Given their revenues and costs specified above, the problem of the lender is to choose rates and fees to maximize the following expected flow profits:

$$\max_{r_{jmt}, f_{jmt}} \Pi_{lt}(r_{jmt}, f_{jmt}) = TR_{lt}(r_{jmt}, f_{jmt}) - TC_{lt}\left(q_{i1}, ..., q_{iJ_{lt}}\right). \tag{9}$$

In the data, we observe that UK lenders adopt national prices for identical products across geographic markets, i.e., $r_{jmt} = r_{jt}$ and $f_{jmt} = f_{jt}$. Hence, lenders choose the rate r_{jt}

to satisfy the following optimality condition:

$$\frac{\partial \Pi_{lt}}{\partial r_{jt}} = \sum_m \sum_i s_{ijmt} q_{ijmt} + \sum_m \sum_i s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} (r_{jt} - mc_{jt}) + \sum_m \sum_{k \in J_l} \sum_i \frac{\partial s_{ikmt}}{\partial r_{jt}} \left(\frac{f_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt} - mc_{kt}) \right) = 0. \tag{10}$$

Thus, the summations aggregate households and markets at the product level in a quarter. The first term gives the additional profits from the higher rate on the quantity sold; the second term captures the changes in loan demand from a higher rate; the third term collects the impact of a higher rate on the choice probability for all products J_l offered by lender l.

Solving for the optimal interest rate yields:

$$r^*_{jt} = \overbrace{mc_{jt}}^{\text{Marginal cost}} - \frac{\overbrace{\sum_m \sum_i s_{ijmt} q_{ijmt}}^{\text{Mark-up}}}{\sum_m \sum_i \left(q_{ijmt} \frac{\partial s_{ijmt}}{\partial r_{jt}} + s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} \right)} - \frac{\overbrace{\frac{f^*_{jt} - a_{jt}}{\tau_{jt}} \sum_m \sum_i \frac{\partial s_{ij}}{\partial r_j}}^{\text{Net Fee Income}}}{\sum_m \sum_i \left(q_{ijmt} \frac{\partial s_{ijmt}}{\partial r_{jt}} + s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} \right)} \underbrace{- \frac{\sum_m \sum_{k \neq j \in J_l} \sum_i \frac{\partial s_{ikmt}}{\partial r_{jt}} \left(\frac{f^*_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r^*_{kt} - mc_{kt}) \right)}{\sum_m \sum_i \left(q_{ijmt} \frac{\partial s_{ijmt}}{\partial r_{jt}} + s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} \right)}}_{\text{Other products}}. \tag{11}$$

Note that if there are no fees and no application costs, all lenders offer only one product, borrowers make only the discrete product choice, then equation (11) collapses to the standard mark-up pricing formula with one price: $r^*_{jt} = mc_{jt} - \frac{\sum_i s_{ijt}}{\sum_i \frac{\partial s_{ijt}}{\partial r_{jt}}}$.

Similarly, the optimal fee of product j satisfies:

$$\frac{\partial \Pi_{lt}}{\partial f_{jt}} = \sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}} + \sum_m \sum_i s_{ijmt} \frac{\partial q_{ijmt}}{\partial f_{jt}} (r_{jt} - mc_{jt}) + \sum_m \sum_{k \in J_l} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left(\frac{f_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt} - mc_{kt}) \right) = 0. \tag{12}$$

The first term of equation (12) gives the change in lender profits due to higher fees on the current market share of product j; the second term gives the change in lender profits due the changes in loan amount; the third term collects the effect of a higher fee on the choice

probability of all products offered by the lender. Solving for the optimal fee yields:

$$\frac{f^*_{jt}}{\tau_{jt}} = \overbrace{\frac{a_{jt}}{\tau_{jt}}}^{\text{Application cost}} - \overbrace{\frac{\sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}}}^{\text{Mark-up}} - \overbrace{\frac{\sum_m \sum_i \left(s_{ijmt} \frac{\partial q_{ijmt}}{\partial f_{jt}} + q_{ijmt} \frac{\partial s_{ijmt}}{\partial f_{jt}} \right)}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}} \left(r^*_{jt} - mc_{jt} \right)}^{\text{Net Interest Income}}$$
$$\underbrace{- \frac{\sum_m \sum_{k \neq j \in J_l} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left(\frac{f^*_{kt} - a_{kt}}{\tau_k} + q_{ikmt} (r^*_{kt} - mc_{kt}) \right)}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}}}_{\text{Other products}}. \tag{13}$$

Equations (11) and (13) describe a negative relation between the rate and the fee of each product j, consistent with the empirical evidence of Section 2.1. Rates and fees are substitute tools for lenders to increase profits; their optimal setting depends on funding costs and on application costs, as well as on the relative elasticities of households demand with respect to each of them.

Lenders' optimal rates and fees, as well as borrowers' optimal choice of mortgage product and of loan amount, characterize the equilibrium in the mortgage market.

5 Estimation and Identification

In this section we describe the parametric assumptions that we make in order to estimate the model. Moreover, we discuss the key variations in the data that we exploit to identify the model parameters, as well as how we address endogeneity concerns arising from unobservable product characteristics.

5.1 Estimation

Demand. The demand model in Section 4.1 predicts household choice of mortgage product and of loan amount as a function of observable and unobservable products attributes, observable and unobservable household characteristics/preferences, and a vector of parameters that we estimate.

We build on Train (1986) and assume that the indirect utility $\bar{V}_{ijmt}$ equals:

$$\bar{V}_{ijmt} = \frac{\gamma_m}{1-\psi_m}\left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right)^{1-\psi_m} + \mu_m \exp(\delta_{jmt} + \eta_m D_i + \zeta_i) + \lambda_m A_{ij(l)mt}, \tag{14}$$

where $\delta_{jmt} = -\alpha_m r_{jt} + \beta_m X_j + \xi_{jmt}$ capture all observed and unobserved product attributes.

Moreover, we assume that ε_{ijmt} in equation (2) is identically and independently distributed across borrowers and mortgage products with a type-I extreme value distribution. Hence, the probability p_{ijmt} that borrower i chooses product j in market m and quarter t conditional on his unobserved heterogeneity ζ_i equals:

$$p_{ijmt}(\zeta_i) = \frac{\exp(\bar{V}_{ijmt})}{\sum_{j'=0}^{J_i}\exp(\bar{V}_{ij'mt})}.$$

Assuming that ζ_i follows a normal distribution with variance σ_m, the unconditional probability that borrower i chooses product j in market m in quarter t equals:

$$s_{ijmt} = \int_{\zeta} p_{ijmt}(\zeta_i) dF(\zeta_i).$$

Roy's identity yields the following loan demand function q_{ijmt} for borrower i in market m and quarter t, conditional on choosing product j:

$$\ln(q_{ijmt}) = \ln\left(-\frac{\frac{\partial \bar{V}_{ijmt}}{\partial r_{jmt}}}{\frac{\partial \bar{V}_{ijmt}}{\partial Y_i}}\right) = \ln\left(\frac{\mu_m \alpha_m}{\gamma_m}\right) + \psi_m \ln\left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right) + \delta_{jmt} + \eta_m D_i + \zeta_i. \tag{15}$$

From equation (15) and the assumption that ζ_i follows a normal distribution, the probability of the conditional loan demand is:

$$f\left(\ln(q_{ijmt}) | j \neq 0\right) = \frac{1}{\sqrt{2\pi\sigma_m^2}} \exp\left(-\frac{\left(\ln(q_{ijmt}) - \ln\left(\frac{\mu_m\alpha_m}{\gamma_m}\right) - \psi_m \ln\left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right) - \delta_{jmt} - \eta_m D_i\right)^2}{2\sigma_m^2}\right).$$

Therefore, the log-likelihood that borrower i chooses product j in market m quarter t

and loan amount q_{ijmt} is:

$$\ln(L_i) = \sum_{j=0}^{J_i} \mathbb{I}_{ijmt} \left(\ln(s_{ijmt}) + \ln(f(\ln(q_{ijmt})|j \neq 0)) \right), \tag{16}$$

where $\mathbb{I}_{ijmt}$ is an indicator variable equal to one if borrower i chooses product j, and zero otherwise.

We proceed in two step to estimate the demand parameters. In the first step, we include a full set of product-market-quarter fixed effects δ_{jmt} in the log-likelihood to account for the possible correlation between the interest rate r_{jt} and the fees f_{jt} with unobservable product type characteristics ξ_{jmt}. Then, we maximize the joint log-likelihood function at the market level, $\mathcal{L}_m = \sum_t \sum_i ln(L_i)$, separately for each of the 24 markets that we defined in Section 4.1 as a combination of income (above or below the median income), age (above or below the median age), and geographic region (London, South, Mid, North, Wales, Scotland). Thus, for each market m, we obtain the utility parameters γ_m, ψ_m, η_m, and λ_m, the scaling factors σ_m and μ_m, and the product-market-quarter fixed effects δ_{jmt}.

In the second step, we estimate, separately for each market m, the coefficients α_m and β_m of the interest rate r_{jt} and of the other product characteristics X_j through an IV regression whose dependent variable is the product-market fixed effect $\hat{\delta}_{jmt}$ estimated in the first step:

$$\hat{\delta}_{jmt} = -\alpha_m r_{jmt} + \beta_m X_j + \xi_{jmt}. \tag{17}$$

We describe in Section 5.2 the supply-side instruments that we employ to obtain consistent estimates of the parameters of (17).

Supply. The estimation of the supply side parameters relies on lenders' optimal pricing. For now, we assume that application costs a_{jt} equal zero and we back out the unobserved marginal cost mc_{jt} of each product j by inverting equation (11), thereby solving for this cost as a function of its observed interest rate and estimated mark-up.

Moreover, we combine and rewrite equations (7) and (8) as follows:

$$mc_{jt} = c^o_{jt} + \begin{cases} p_{FLS,lt} + \omega_{0,lt} & \text{if } FLS_t = 0, \\ p_{FLS,lt} + \omega_{1,lt} & \text{if } FLS_t = 1 \text{ and } Q_{FLS,lt} = 0, \\ p_{FLS,lt} + \omega_{2,lt} & \text{if } FLS_t = 1 \text{ and } 0 < Q_{FLS,lt} < Q_{\overline{FLS},lt}, \\ p_{FLS,lt} + \omega_{3,lt} & \text{if } FLS_t = 1 \text{ and } Q_{FLS,lt} = Q_{\overline{FLS},lt}, \end{cases} \tag{18}$$

where FLS_t is an indicator variable equal to one after the introduction of FLS, and zero otherwise; $\omega_{\cdot,lt}$ are parameters such that $\omega_{1,lt} \leq 0 = \omega_{2,lt} \leq \omega_{3,lt}$ and we expect $\omega_{0,lt} > 0$. In practice, all lenders that borrow their full allowance from the FLS facilities have negligible market shares in the mortgage market and, thus, we include them in households' outside option in the estimation of demand. Thus, we do not recover marginal costs of these lenders and do not estimate $\omega_{3,lt}$.

We further let the cost c^o_{jt} be a flexible function of observed and unobserved characteristics of mortgage product j, i.e., $c^o_{jt} = \gamma^c_X X_j + \kappa^c_{jt}$. Hence, we estimate the following regression:

$$mc_{jt} - p_{FLS,lt} = \gamma^c_l + \gamma^c_t + \gamma^c_1 1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0) + \gamma^c_X X_j + \kappa^c_{jt}, \tag{19}$$

where mc_{jt} is the estimated marginal cost; $p_{FLS,lt}$ is the interest rate at which lender l borrows from the FLS facilities in quarter t (or will borrow in periods if $FLS_t = 0$, or could borrow if $Q_{FLS,lt} = 0$); γ^c_l are lender fixed effects; γ^c_t are quarter fixed effects; $1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0)$ is an indicator variable equal to one when FLS facilities are available and lender l borrows from them in quarter t; X_j are the product characteristics; and κ^c_{jt} is a structural error term capturing unobservable determinants of marginal costs. We can obtain estimates of the $\omega_{\cdot,lt}$ parameters in (18) by combining lender and quarter fixed effects with the coefficient of the indicator variable $1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0)$. In practice, since $p_{FLS,lt}$ does not vary within lender over time, the lender fixed effects γ^c_l fully capture the cross-sectional variation across lenders.

The participation in the FLS is a choice of each lender and, thus, the indicator variable $1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0)$ is endogenous. Thus, we estimate equation (19) exploiting instruments that we describe in Section 5.2.

5.2 Identification

Demand. The estimation of the demand parameters faces two main endogeneity concerns. First, the discrete-continuous choice generates selection bias if we do not account for the discrete product choice when we estimate the continuous quantity choice. To address this concern, we estimates the discrete and continuous choice jointly. As we recounted above, the local branch network enters in the discrete choice only; specifically, we exploit variation in the branch network along with variation on the location of borrowers' houses at the postcode level to identify the effect of lenders' local branch networks on borrowers' choice among lenders.

Second, lenders simultaneously set interest rates and origination fees, which could be correlated with unobserved product characteristics. For example, a lender could raise the interest rate and the origination fee on its mortgage products, while lowering its underwriting standards. We would not observe the latter, but we could observe borrowers (risky ones, in particular) choosing the products of this lender despite their higher rates and fees; hence, we would mistakenly infer that these borrowers do not respond to prices, whereas their choice depend on the lender's unobserved underwriting standards.

Our two-step estimation procedure deals with the possible correlation between the fees f_{jt} and the unobservable characteristic ξ_{jmt} by including product-market fixed effects δ_{jmt} that capture all the variation at the product-market level. However, we can still identify the parameters γ_m and ψ_m that determine how origination fees affect demand because: 1) Origination fees are lump-sum. This implies that borrowers should be indifferent between a decrease in their income Y_i and a corresponding increase in fees $\frac{f_{jt}}{t_{jt}}$ by the same amount—i.e., only $Y_i - \frac{f_{jt}}{t_{jt}}$ matters to them, which varies across borrowers and across products. 2) Roy's identity restricts all parameters—most notably, the product-market-quarter fixed effects—that enter the discrete product demand and the continuous loan demand to be the same (up to a scaling factor). Hence, any residual variation in the loan demand that the fixed effects δ_{jmt} do not capture and that is correlated with $Y_i - \frac{f_{jt}}{\tau_{jt}}$ identifies the parameter ψ_m in the continuous-choice equation; similarly, any residual variation in the product demand that the fixed effects δ_{jmt} do not capture and that is correlated with $Y_i - \frac{f_{jt}}{\tau_{jt}}$ identifies the parameter γ_m in the discrete-choice equation.

Moreover, our estimation deals with the possible correlation between the interest rate

r_{jt} and the unobservable characteristic ξ_{jmt} in regression (17) by exploiting two cost shifters of the interest rate r_{jt} previously employed and motivated in Benetton (2018) and Robles-Garcia (2019): 1) Risk-weighted capital requirements. These capital requirements affect lenders' cost of supplying a specific product, and they vary across products and across lenders, depending on whether they use an internal model or a standardized approach to measure credit risk. 2) Euro interest rates swaps for two, three, and five years. Swap rates are a hedging instrument that lenders use when selling mortgages with fixed periods of two, three, and five years, respectively; thus, they vary across time and across products. Our exclusion restriction is that, once we control for lender and market fixed effects, these two instruments do not affect borrowers' choice directly, but they do indirectly through their effects on mortgages rates only.

The co-variation between the exogenous product characteristics X_j and borrowers' choices identifies the other parameters in equation (17).

Supply. The main parameter of interest in the cost equations is the coefficient γ_1^c of the indicator variable $1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0)$, which equals one when the FLS facilties are available and lender l borrows from them in quarter t, and zero otherwise. Thus, the indicator variable $1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0)$ varies over time, before and after the implementation of the policy, and in the cross-section across because some lenders do not borrow new funds from FLS in every quarter. Hence, we can control for lender and quarter fixed effects and exploit the joint variation across lenders and over time to identify the effects of FLS on lenders' costs.

Nevertheless, lenders endogenously decide whether or not to borrow from the FLS facilities in quarter t, and this decision could be correlated with potentially unobservable, time-varying bank characteristics that we may not be able to fully control for with our set of fixed effects. Hence, we implement an instrumental variable approach, using the fraction of assets held as cash in quarter t as instrument. The idea of this instrument is that a large fraction of assets held as cash suggests that a bank may have few lending opportunities in quarter t (i.e., face a lower demand) and, thus, it may not need additional FLS funds.

The identification of the effect of exogenous product characteristics X_j in equations (19) relies on how these characteristics—such as length of the fixation period, which captures lenders' interest rate risk, and the maximum loan-to-values, which captures default risk—

Table 4: Demand Parameters

	α_r	$\beta_{highLTV}$	β_{Fix5}	λ	ψ	γ	μ	σ
Mean coefficient	0.058	0.033	0.014	0.039	0.617	0.822	11.685	0.256
Mean standard error	(0.008)	(0.011)	(0.007)	(0.353)	(0.002)	(0.340)	(0.029)	(0.014)

Note: Mean coefficients is the average of the estimated demand parameters across different groups. Mean standard error is the average of the estimated standard errors across different groups. All estimates include lender and market fixed effects. The standard error for the parameters in the first stage are computed by the inverse of the information matrix; the standard errors for the mortgage attributes estimated in the second stage are clustered at the product level.

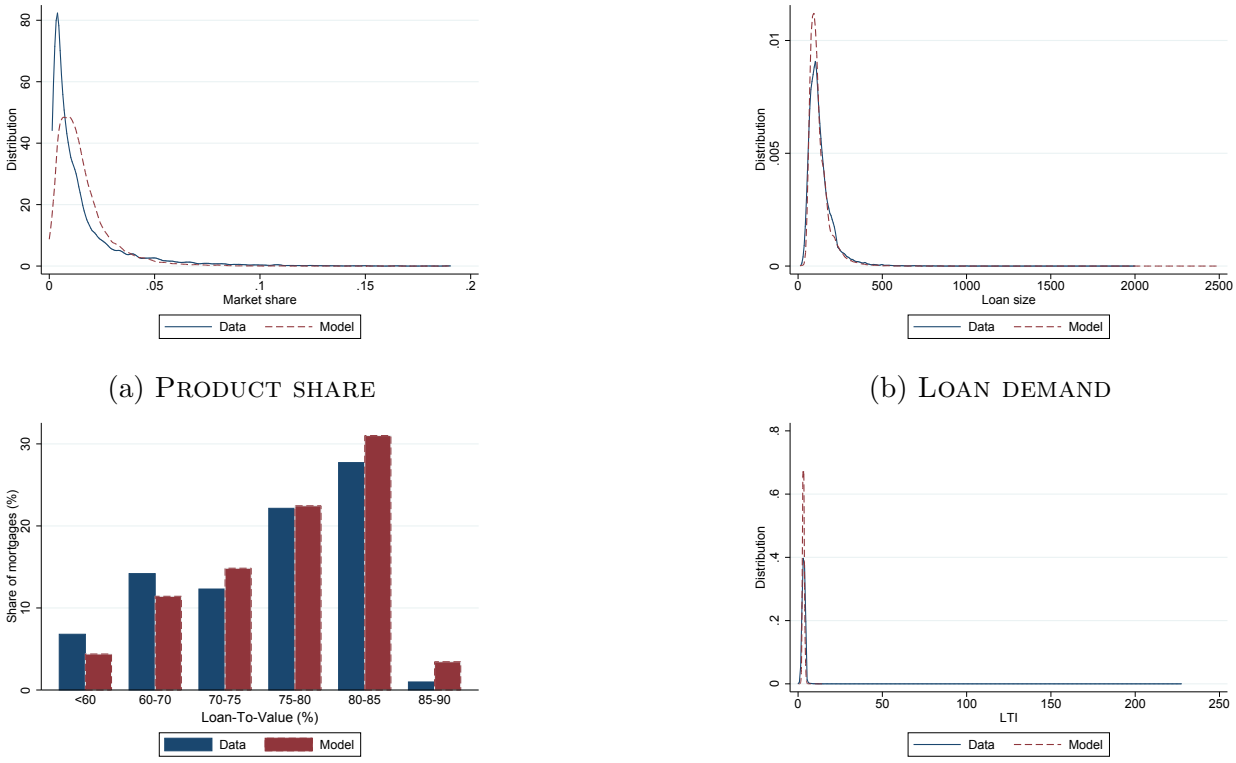
covary with marginal costs mc_{jt}.

5.3 Results

Demand. Table 4 collects the main demand parameters. We report the average of each parameter across groups. Figures A2 and A3 in Appendix D display the heterogeneity of these estimates across different groups. Borrowers prefer mortgage with a higher maximum loan-to-value limit and fixed-rate mortgages with a longer fixation period, all else equal. A higher number of branches in a location has a positive effect on borrowers' product demand, though this coefficient is not precisely estimated.

Figure 9 displays several plots that illustrate how the model fits the data (see also Table A1 in Appendix D). Overall, the fit is quite good, although the model slightly underpredicts that many products have a small market share (panel (a)) and that some borrowers choose low-LTV mortgages (panel (c)).

Given that borrowers' elasticities to rates and fees play an important role for our counterfactual analyses, in Table 5 we report the demand elasticities to the interest rate and the origination fee for the average product, as well as for different lenders and leverage levels. Panel A reports the elasticity of loan demand with respect to the interest rate. We find that a 100-basis-point increase in the interest rate leads to a decrease in loan demand by approximately six percent. The resulting elasticity of loan demand is on average -0.24, varying from -0.34 at the tenth percentile to -0.14 at the ninetieth. The elasticity of loan demand is slightly higher for the largest four banks at -0.24 than for the other banks at -0.22. The heterogeneity of the elasticity across mortgages with different LTVs is larger than that across lenders. The average loan demand elasticity is -0.21 for products with a leverage below 85 and it reaches



(a) Product share

(b) Loan demand

(c) LTV

(d) LTI

Figure 9: Model fit. The charts shows the estimates of the structural demand parameters in different cells given by income, age and region.

−0.30 for products with a leverage above 85.

In Panel B of Table 5 we report the discrete elasticity of the product demand with respect to the interest rate. We find that, on average, a one-percent increase in the rate leads to a 5.8-percent decrease in the market share, which is slightly higher than previous studies of UK and US mortgage markets (Benetton, 2018; Buchak et al., 2018a). The elasticity is, perhaps surprisingly, slightly larger for the big four banks than for the other banks, and considerably larger for high-LTV products relative to low-LTV products.

In Panel C of Table 5 we report the elasticity of the continuous-choice loan demand to fees. We find that, on average, a one-percent increase in the fee leads to a decrease in loan demand by 0.01-percent. To give an idea of the magnitude, going from a zero-fee mortgage to a mortgage with a £1,000 fee will decrease loan demand by almost two percent. The percentiles of the elasticity of loan demand with respect to the origination fee document a considerable heterogeneity across markets: in some markets, borrowers have an elasticity to

Table 5: Demand Elasticities to Rates and Fees

	mean	sd	p10	p50	p90
Panel A: Elasticity rate - continuous					
Total	-0.236	0.081	-0.343	-0.226	-0.141
By lender					
Big 4	-0.244	0.084	-0.354	-0.231	-0.146
Others	-0.218	0.072	-0.311	-0.209	-0.132
By LTV					
LTV≤85	-0.214	0.067	-0.300	-0.208	-0.132
LTV>85	-0.298	0.086	-0.410	-0.290	-0.194
Panel B: Elasticity rate - discrete					
Total	-5.787	2.105	-8.436	-5.516	-3.438
By lender					
Big 4	-5.947	2.170	-8.698	-5.678	-3.506
Others	-5.432	1.904	-7.852	-5.172	-3.344
By LTV					
LTV≤85	-5.336	1.920	-7.717	-5.089	-3.221
LTV>85	-7.077	2.074	-9.625	-6.892	-4.690
Panel C: Elasticity fee - continuous					
Total	-0.013	0.012	-0.031	-0.010	0.000
By lender					
Big 4	-0.014	0.012	-0.033	-0.011	0.000
Others	-0.010	0.010	-0.023	-0.008	0.000
By LTV					
LTV≤85	-0.013	0.012	-0.031	-0.011	0.000
LTV>85	-0.011	0.011	-0.026	-0.008	0.000
Panel D: Elasticity fee - discrete					
Total	-0.052	0.054	-0.134	-0.037	0.000
By lender					
Big 4	-0.053	0.054	-0.134	-0.043	0.000
Others	-0.048	0.055	-0.134	-0.032	0.000
By LTV					
LTV≤85	-0.054	0.054	-0.136	-0.043	0.000
LTV>85	-0.044	0.054	-0.123	-0.024	0.000

Note: Panel A shows the elasticity of loan demand with respect to the rate. Panel B shows the elasticity of product demand with respect to the rate. Panel C shows the elasticity of loan demand with respect to the fee. Panel D shows the elasticity of product demand with respect to the fee. The different elasticities are computes using the formulas in Appendix C.

fees equal to -0.03, whereas in others they have an elasticity to fees almost equal to zero. However, the heterogeneity in the elasticity with respect to the origination fee between large and small lenders, and between low-LTV and high-LTV products, is small.

Finally, in Panel D of Table 5 we report the elasticity of the discrete-choice product demand to fees. On average, a one-percent increase in the fee leads to a 0.05-percent decrease in the market share, with a large heterogeneity across products and markets: some display an elasticity -0.13, whereas others do not seem to respond to fees at all. We do find minor differences in the elasticity with respect to the origination fee between large and small lenders, while low-LTV products have a slightly higher elasticity than high-LTV products—i.e., -0.05 versus -0.04, respectively.

To gain a better sense of the relative magnitudes of these different demand elasticities with respect to rates and fees, we calculate the decrease in interest rates that fully offsets a £1000 increase in the origination fee in borrowers' demand functions. Such increase requires an average decrease in the interest rate of approximately 40 basis points to keep the continuous loan demand (15) constant, and of approximately 12 basis points to keep the indirect utility (14) constant and, thus, the discrete product demand constant. Hence, these magnitudes straddle that of the empirical "exchange-rate" between rates and fees that we reported in Table 2.

Supply. Table 6 collects the coefficient estimates of equation (19). The dependent variable is the estimated marginal cost and the main coefficient of interest is that of the indicator variable $1(FLS_t = 1 \text{ and } Q_{FLS,lt} > 0)$, which accounts for the effect of FLS on lenders' marginal costs. We use two specifications: in columns (1)-(3) we include mortgage product characteristics and cost shifters, as well as quarter and lender fixed effects, and in columns (4)-(6) we additionally include bank balance sheet variables.

The OLS estimates reported in column (1) of Table 6 imply that FLS reduced banks' marginal costs by approximately nine basis points; the OLS estimate in column (4) is similar, though slightly lower and less precise.

As we argued in Section 5.2, banks' endogenously choose to participate in the FLS and, thus, this choice can be correlated with unobservable determinants of lenders' marginal costs. Columns (2) and (5) report the first-stage estimates of our IV regressions, showing that our excluded instruments—i.e., the fraction of assets held as cash—is strongly correlated with

Table 6: Cost Parameters

	Marginal costs - FLS cost					
	No lender controls			Cluster lender-time		
	OLS	FS	IV	OLS	FS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Policy treatment:						
Drawing flow > 0	-0.088**		-0.699***	-0.054		-0.569**
	(0.043)		(0.147)	(0.062)		(0.225)
Product characteristics:						
High LTV	0.603***	0.016	0.605***	0.558***	0.017	0.568***
	(0.090)	(0.015)	(0.090)	(0.047)	(0.015)	(0.047)
Variable rate	-0.368***	-0.030	-0.370***	-0.371***	-0.028**	-0.377***
	(0.076)	(0.020)	(0.075)	(0.036)	(0.011)	(0.036)
Fix 5 years	0.233**	0.066***	0.279***	0.234***	0.086***	0.285***
	(0.104)	(0.023)	(0.105)	(0.072)	(0.031)	(0.081)
Cost shifters:						
Risk weights	8.886***	-0.065	8.993***	9.538***	-0.090	9.499***
	(0.970)	(0.129)	(0.968)	(0.560)	(0.181)	(0.562)
Swap rates	0.466***	-0.121***	0.382***	0.475***	-0.143**	0.388***
	(0.128)	(0.043)	(0.131)	(0.103)	(0.055)	(0.122)
Balance sheet variables:						
Sight deposits (%)				-4.541***	-0.147	-3.446**
				(1.342)	(1.850)	(1.701)
Time deposits (%)				-2.916**	-1.809	-2.508*
				(1.223)	(1.500)	(1.331)
Capital ratio (%)				7.609***	-1.935	5.382*
				(2.490)	(2.271)	(2.840)
Assets (log)				1.686***	0.314	1.907***
				(0.447)	(0.518)	(0.527)
Excluded instrument:						
Cash (%)		-8.096***			-8.211***	
		(0.389)			(1.629)	
Time, Region and Lender f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Marginal cost (mean)	2.24	0.24	2.24	2.24	0.24	2.24
F statistic			433.35			25.42
Adjusted R^2	0.83	0.64	0.81	0.84	0.65	0.83
Observations	12,030	12,030	12,030	12,030	12,030	12,030

Note: The dependent variable is the marginal cost of lending. FLS is the cost of FLS funding, which depends on lending growth since the start of FLS. Asset abroad is the share of assets abroad for each lender in the period before the FLS announcement. Standard errors are clustered at the product level.

the decision to borrow from the FLS facilities in quarter t. We should point out that column (5) shows that the additional bank controls do not seem to play a significant role in the first-stage. Columns (3) and (6) report the second-stage IV estimates. They indicate that borrowing from the FLS facilities reduced lenders' funding costs by approximately 57-70 basis points. Given an average marginal cost of about 230 basis points, the FLS decreases marginal costs by approximately 25-30 percent for the average mortgage product.

While our main focus is on the effects of FLS, Table 6 also reports the estimates for other variables that affect the marginal cost of offering a mortgage. Higher risk-weights increase marginal costs, as they raise the capital that lenders need in order to increase mortgage lending. Similarly, higher swap rates also increase marginal costs, as they increase the spread lenders have to pay to exchange the fixed interest rate with the variable benchmark (e.g., Euribor). Product with greater default risk, measured by a higher the loan-to-value, and greater interest rate risk, measured by the longer fixed rate, have higher marginal costs, as expected. Moreover, we find that mortgages with a fully variable rate have lower marginal costs than those with a short-term fixed rate (the baseline category).

6 Counterfactual Analyses

In this section, we use the estimated parameters to study the effect of the FLS, as well as the effects of two-part pricing with rates and fees, on the mortgage market. Specifically, we perform the following counterfactual analyses: 1) we remove the availability of FLS facilities; and 2) we ban the use of fees.

Table 7 reports key outcomes of interest for the baseline case (i.e., the estimated model) and for the alternative counterfactual scenarios that we consider: lenders' marginal cost, mortgage rates and fees, volumes of mortgage originated, lenders' profits, and consumer surplus.

The first row of Table 7 reports market outcomes for the baseline period in which FLS facilities were available—i.e., the first row reports the prediction of our model, which matched the data quite closely, as we showed in Section 5.3. The marginal cost of issuing a mortgage equals 290 basis points in this period. Borrowers paid an average interest rate of 399 basis points and an average origination fee of about £500, resulting in an Annual Percentage Rate

Table 7: Counterfactual Scenarios

	(1) Cost (%)	(2) Rate (%)	(3) Fee (.000)	(4) APR (%)	(5) Loan Size (.000)	(6) Originations	(7) Profit (Million)	(8) Consumer Surplus
Baseline	2.90	3.99	0.50	4.01	106	31,047	50	163
No FLS	3.20	4.27	0.65	4.29	104	30,822	47	162
No Fee	2.89	4.26	0	4.26	105	30,634	49	162

Note: Results from counterfactual analysis. No FLS is a counterfactual in which we shut down the effect of FLS on lenders marginal costs from column (1) in Table 6 and for now we assume no change in fees and that 80% of the increase in marginal cost is pass on to mortgage rates. No Fee is a counterfactual in which we force all products to have zero fees, thus for each product type k there is a unique product j with zero fee and a new equilibrium rate (for now we assume that the new mortgage rates is the highest for the same product type).

(APR) equal to 401 basis points. Column (5) reports the predicted average loan amount, which equals £106,000, whereas column (6) reports the total number of mortgages originated per quarter, which equal 31,047. Finally, quarterly lenders' profits, computed using equation (9), equal 50, whereas consumer surplus, computed using equation (24) in Appendix C, equal 163 millions.

No FLS. In the second row of Table 7, we report the counterfactual case in which we remove the availability of the FLS facilities for lenders. This removal increases lenders' funding costs. Using the estimates from column (3) of Table 6 and assuming $\psi^c = 0$ to shut down the effect of the scheme on lenders' marginal costs, we calculate that, on average, the removal of the scheme increases marginal costs by 30 basis points, from 290 in the baseline case to 320 basis points. Column (2) indicates that interest rates increase by 28 basis points, slightly less than the increase in marginal costs; column (3) indicates that fees increase as well, by approximately 150 pounds. Hence, it is interesting to note that lenders transmit the increase in their funding costs to borrowers using both interest rates and fees. As a result of the increase of both rates and fees, the APR increases. Column (5) shows that the average loan size decreases, since borrowers demand smaller loans as their costs increases. Similarly, column (6) shows a small decline in the number of mortgages originated, as well.

Columns (7) and (8) show that both lender profits and consumer surplus decline relative to the baseline case, as the increase in funding costs decreases overall market surplus. Lender

profits decline by approximately three million per quarter, a decline of approximately six percent relative to baseline profits. Consumer surplus decline by less, one million only. Overall, the comparison between the changes in lender profits and in consumer surplus suggest that lenders appropriated most of the surplus increase due to lower funding costs during the FLS period.

No Fees. Our second counterfactual case focuses on the effects of two-part pricing with rates and fees by considering a ban on origination fees. We think that this is of interest for at least two reasons. First, Greenwood and Scharfstein (2013) document the growth in fees associated with an expansion in household credit, particularly fees associated with residential mortgages. Hence, our model is well suited to understand the contribution of mortgage origination fees to lenders' profits. Second, the financial press recently reported that the Financial Conduct Authority (FCA) is currently considering the regulation of mortgage origination fees (*The Financial Times*, Mortgage lenders under FCA review for masking high fees, December 12, 2016); thus, we can use our estimated model to gain some insights into how such regulation could affect lenders and borrowers.

The third row of Table 7 reports the results of this ban. Column (1) shows that marginal costs changes minimally relative to baseline marginal costs, due to the reallocation of market shares to lower-funding-cost lenders. However, column (2) shows that lenders increase interest rates on mortgage products by 27 basis points when origination fees are capped at zero, as column (3) reports. Column (5) shows that average loan amount decline relative to the baseline by approximately £1,000. Similarly, column (6) shows that the number of mortgages originated declined, as well.

Columns (7) and (8) show that both lender profits and consumer surplus decline relative to the baseline case. However, their decline is smaller than in the case of the removal of the FLS facilities reported in the second row. The reason for the decline in lender profits is simple: while lenders can increase interest rates to respond to the ban of origination fees, the increase in fee income does not fully offset the loss of fee income. The decline in consumer surplus is perhaps surprising, but it is due to the fact that borrowers are more elastic to interest rates than to origination fees and, thus, the increase in interest rates weighs more than the decline in origination fees in borrowers' utility functions.

7 Conclusions

This paper explores a novel channel that can affect the transmission of unconventional monetary policy to the housing sector: price discrimination through two-part tariffs composed of origination fees and interest rates.

First, we provide descriptive evidence on how lenders use this two-part pricing in the U.K. mortgage market and how unconventional monetary policy may have affected their pricing strategy. Then, we develop and estimate a structural demand-and-supply model with rich borrower heterogeneity to quantify the effect of unconventional monetary policy on lending rates, the total cost of borrowing, and lenders' profits. Finally, we use the estimated model to compute the welfare costs and benefits of unconventional monetary policies across lenders and borrowers in the absence of this two-part pricing strategy.

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Appendix

The appendix is structured as follows. Section B details how we construct our main dataset by merging the differences data sources on mortgage choices from the Financial Conduct Authority, products offered from Moneyfacts and lenders borrowing from the Bank of England. Section D provides additional details about the estimation approach and on the fit of the model.

A Mortgage pricing across LTV bands in the PSD

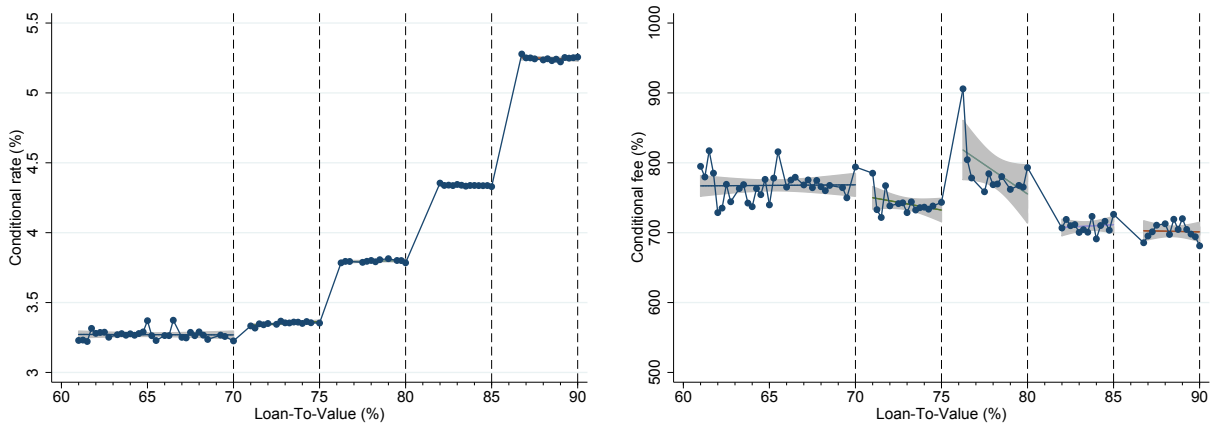


Figure A1: LTV PRICING

Note: Panel (a) shows how the average initial interest rates on mortgage originations vary within and across LTV bands. Panel (b) displays a similar picture for origination fees. Source: the Financial Conduct Authority Product Sales Database. Sample: for interest rates, 2010-2014; for fees, 2015, which is the first year since when origination fees are available in the PSD.

Figure A1 illustrates the main pricing structure of UK mortgages using the universe of mortgage originations from the PSD. Specifically, the left panel displays that the interest rate varies across LTV bands, with (almost) no variation within bands, consistent with the pattern reported in (Cloyne et al., 2018; Benetton, 2018). In other words, UK lenders seem to price default risk almost exclusively through LTV bands, and not through borrower-specific pricing, as it is instead the case in the US mortgage market. Moreover, this panel motivates us to model borrowers' choice as a discrete-choice among these LTV bands, lenders, and other product characteristics. The right panel displays that fees –which we observe in the

PSD only since 2015– exhibit very limited variation across and within bands, potentially suggesting that lenders use them mainly to extract consumer surplus.

B Data Construction

- Step 1: Matching mortgages with time-lender-LTV band-rate to moneyfacts to recover dealtype.
  - Moneyfacts missing 2013 month 6
  - Sometimes cannot find LTV band in moneyfacts corresponding to LTV band in PSD. Cases in which no jumps in PSD. E.g. Nationwide in November 2009 does not have 75-80 band, only max 70-75 and 80-85, but then introduce it later.
  - Sometimes more than one dealtype for the same interest rate-lender-LTV band-month. E.g. 2 and 3 years fixed with different fees.
  - We manage to keep 456,323 out of 517,546 (88%)
  - Nationwide specialized in 3 years fixed. Checked with moneyfacts.
- Step 2: Matching mortgages with time-lender-LTV band-dealtype-rate to recover product rate (as a check) and fees.
- Step 3: Predicting dealtype and fee level for mortgages when both rates and dealtype missing (42%, approx 350K obs). First
  - Rename lender to outside if dealtype is different from zero, two, three and five. Rename lender to outside if fix zero and floating five. Less than 1%.
  - Ordered logit model for dealtype. We run regression for each ratetype (FRM,ARM) and LTV band with dummy for age, income, region and time. We compute the predicted probabilities and compare it with the empirical frequencies. We take the highest predicted proability if larger than the empirical frequency. Otherwise we take the one with the largerst positive difference with the empirical frequency.
  - Ols model for interest rate. We predict the interest rate with dummies for product (excluding lender) and age-income-region
  - We match the mortgages with imputed dealtype and rate with moneyfacts and take the interest with the smallest difference to recover interest and fees

C Model: Additional Material

Demand elasticities. The individual loan demand elasticity ($\epsilon^{r,q}_{ijmt}$) and individual product demand elasticity ($\epsilon^{r,s}_{ijmt}$) with respect to the interest rate equal:

$$\epsilon^{r,q}_{ijmt} = \frac{\partial q_{ijmt}}{\partial r_{jt}} \frac{r_{jt}}{q_{ijmt}} = \frac{\partial \ln(q_{ijmt})}{\partial r_{jt}} r_{jt} = -\alpha_m r_{jt}, \tag{20}$$

$$\epsilon^{r,s}_{ijmt} = \frac{\partial s_{ijmt}}{\partial r_{jt}} \frac{r_{jt}}{s_{ijmt}} = -\alpha_m \mu_m \exp(-\alpha_m r_{jt} + \beta_m X_j + \xi_{jmt} + \zeta_i)(1 - s_{ijmt}) r_{jt}. \tag{21}$$

Similarly, the elasticities with respect to the fee equal:

$$\epsilon^{f,q}_{ijmt} = \frac{\partial q_{ijmt}}{\partial f_{jt}} \frac{f_{jt}}{q_{ijmt}} = -\frac{\psi_m}{\left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right)} \frac{f_{jt}}{\tau_{jt}}, \tag{22}$$

$$\epsilon^{f,s}_{ijmt} = \frac{\partial s_{ijmt}}{\partial f_{jt}} \frac{f_{jt}}{s_{ijmt}} = -\frac{\gamma_m (1 - s_{ijmt})}{\left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right)^{\psi_m}} \frac{f_{jt}}{\tau_{jt}}. \tag{23}$$

We compute the elasticities at the product-market-quarter level by averaging across borrowers in each market m and quarter t.

Consumer Surplus. The expected compensating variation $E[cv]$ for a change in interest rate, all else equal, equals:

$$E\left[\max_{j \in J^0} U(y, r^0_j, X_j, \epsilon_j)\right] = E\left[\max_{j \in J^0} U(y, r^1_j - cv, X_j, \epsilon_j)\right], \tag{24}$$

where r^0_j is the interest rate of product j before the change and r^1_j is the interest rate after the change. Hence, the difference in expected consumer surplus equals:

$$\Delta E[CS] = \frac{1}{\gamma \left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right)^{-\psi}} \left[\ln\left(\sum_{j=1}^{J^1} \exp(V^1_j)\right) - \ln\left(\sum_{j=1}^{J^0} \exp(V^0_j)\right)\right], \tag{25}$$

where $\gamma \left(Y_i - \frac{f_{jt}}{\tau_{jt}}\right)^{-\psi}$ is the marginal utility of income.

D Estimation: Additional Material

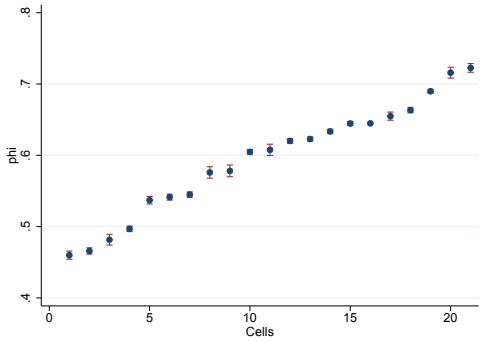
Table A1: Fit of the model

	mean	**sd**	**p10**	**p50**	**p90**
loan value					
Data	134.8	80.5	66.3	115.5	217.5
Model	124.5	66.5	69.0	107.1	201.3
LTI					
Data	3.4	2.0	2.2	3.4	4.6
Model	3.1	0.6	2.4	3.1	3.8
Product shares					
Data	1.8	3.0	0.2	0.8	4.4
Model	1.9	2.5	0.6	1.4	3.2
LTV					
Data	80.7	7.5	70.0	80.0	90.0
Model	78.5	5.3	71.4	79.0	85.1

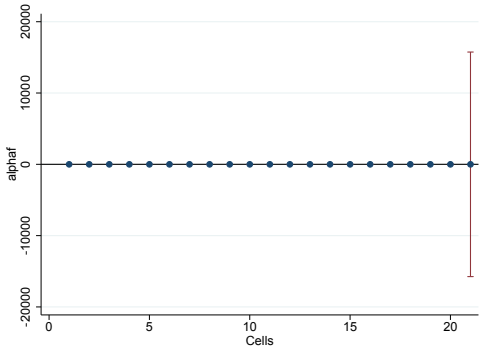
Note: write.

Figure A2: **Demand estimates: first stage**

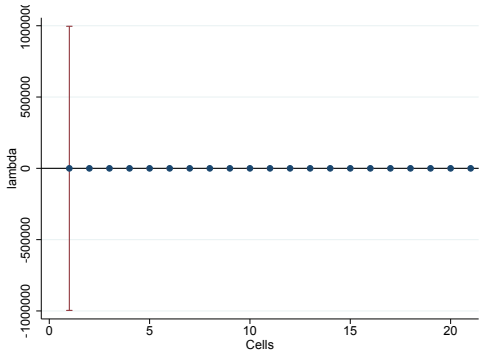
Notes: The charts shows the estimates of the structural demand parameters in different cells given by income, age and region.



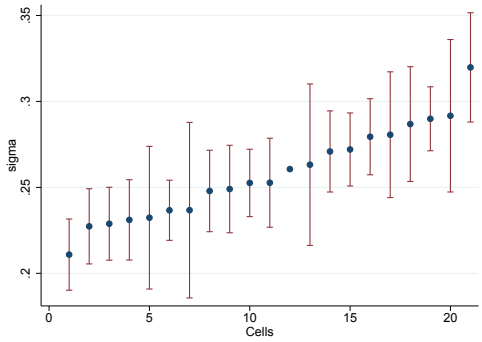
(a) Income (ϕ)



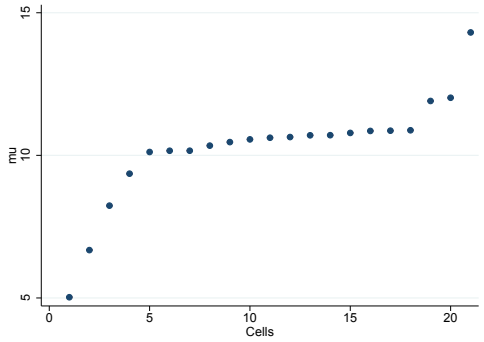
(b) Fee (α_f)



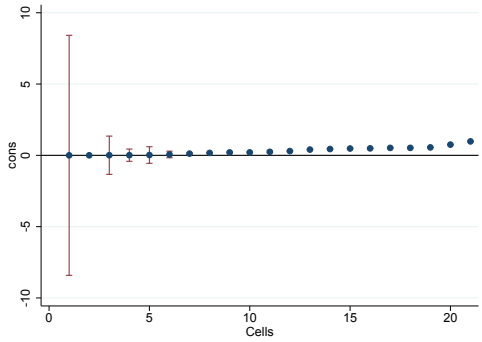
(c) Branches (λ)



(d) Variance (σ)



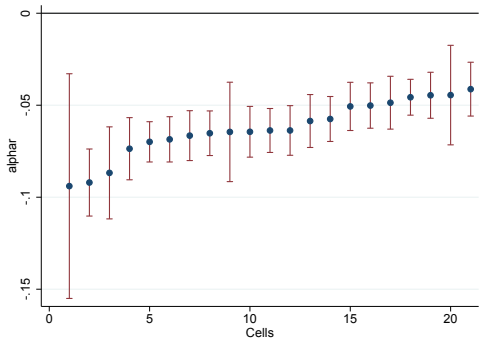
(e) Scaling (μ)



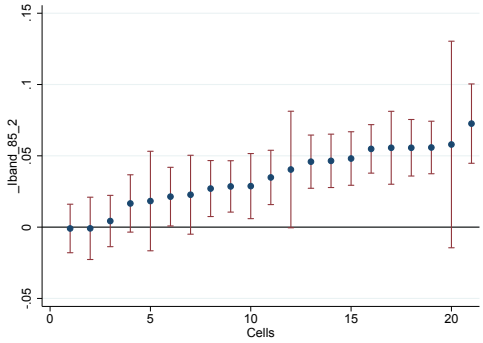
(f) Constant

Figure A3: **Demand estimates: second stage**

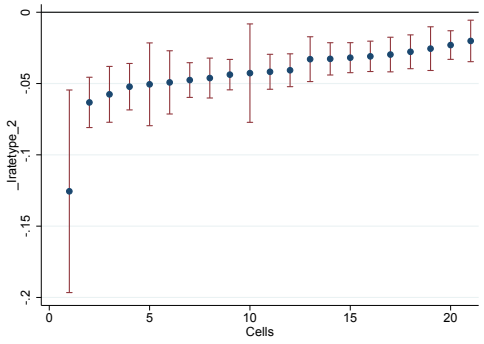
Notes: The charts shows the estimates of the structural demand parameters in different cells given by income, age and region.



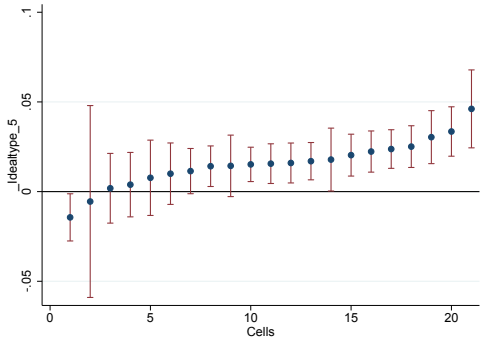
(a) Interest (α_r)



(b) High LTV



(c) Variable rate



(d) 5-years fixed

Table A2: Structural supply parameters: OLS

	Actual borrowing		Ex-post lending	
	(1)	(2)	(3)	(4)
FLS outstanding (dummy)	-0.576***			
	(0.063)			
FLS outstanding (log)		-0.061***		
		(0.007)		
Lending growth > 0 (dummy)			-0.350***	
			(0.067)	
Reduction in mc (%)				-0.283***
				(0.057)
Risk weights	8.818***	8.493***	8.121***	8.055***
	(0.794)	(0.787)	(0.796)	(0.797)
Swap rates	0.286***	0.311***	0.339***	0.335***
	(0.097)	(0.099)	(0.101)	(0.102)
High LTV	0.547***	0.573***	0.600***	0.606***
	(0.076)	(0.077)	(0.079)	(0.079)
Variable rate	-0.085	-0.068	-0.062	-0.070
	(0.072)	(0.074)	(0.078)	(0.079)
Fix 5 years	0.234***	0.225***	0.215***	0.214***
	(0.073)	(0.075)	(0.076)	(0.076)
Time f.e.	Yes	Yes	Yes	Yes
Region f.e.	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes
Marginal cost (mean)	2.33	2.33	2.33	2.33
Adjusted R^2	0.82	0.82	0.81	0.81
Observations	12,489	12,489	12,489	12,489

Note: The dependent variable is the marginal cost of lending. FLS outstanding dummy is a variable equal to one in the post FLS period for lenders with a positive outstanding amount of FLS borrowing. FLS outstanding log is equal to the logarithm of the outstanding amount of FLS borrowing interacted with a dummy equal to one in the post period. Lending growth >0 is a dummy equal to one in the post FLS period for lenders with a positive lending growth since the start of FLS. Reduction in marginal costs is a the reduction of marginal costs as a result of different lending growth since the start of FLS: 1.25% (125 basis points) if lending growth is > 5%; 0 if lending growth < -5% and 0.75% (75 basis points) otherwise.

Table A3: Structural supply parameters: First Stage

	FLS outstanding (dummy)	Reduction in mc (%)	Lending growth > 0 (dummy)	Reduction in mc (%)
	(1)	(2)	(3)	(4)
Assets Abroad × Post	-0.014***	-0.084***	-0.008***	-0.015***
	(0.003)	(0.027)	(0.003)	(0.003)
Risk weights	1.149***	6.389**	0.162	-0.124
	(0.311)	(2.932)	(0.391)	(0.383)
Swap rates	-0.062	-0.489	-0.050	-0.040
	(0.057)	(0.500)	(0.055)	(0.051)
High LTV	-0.083***	-0.390*	0.005	0.030
	(0.025)	(0.236)	(0.033)	(0.033)
Variable rate	0.008	0.291	0.057*	0.049
	(0.020)	(0.199)	(0.032)	(0.034)
Fix 5 years	0.022	0.182	0.021	0.007
	(0.035)	(0.313)	(0.036)	(0.033)
Time f.e.	Yes	Yes	Yes	Yes
Region f.e.	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes
F statistic	21.19	9.66	6.73	22.40
Observations	12,489	12,489	12,489	12,489

Note: The dependent variable are different measures that capture the FLS treatment. FLS outstanding dummy is a variable equal to one in the post FLS period for lenders with a positive outstanding amount of FLS borrowing. FLS outstanding log is equal to the logarithm of the outstanding amount of FLS borrowing interacted with a dummy equal to one in the post period. Lending growth >0 is a dummy equal to one in the post FLS period for lenders with a positive lending growth since the start of FLS. Reduction in marginal costs is a the reduction of marginal costs as a result of different lending growth since the start of FLS: 1.25% (125 basis points) if lending growth is > 5%; 0 if lending growth < -5% and 0.75% (75 basis points) otherwise. The excluded instrument is the fraction of asset abroad from the bank balance sheet before the FLS interacted with a dummy equal to one is the post FLS period.

Table A4: Structural supply parameters: Reduced Form - IV

	Reduced form	Actual borrowing		Ex-post lending	
	(1)	(2)	(3)	(4)	
Asset Abroad × Post	0.006**				
	(0.002)				
FLS outstanding (dummy)		-0.457***			
		(0.123)			
FLS outstanding (log)			-0.074***		
			(0.019)		
Lending growth > 0 (dummy)				-0.759***	
				(0.234)	
Reduction in mc (%)					-0.415***
					(0.126)
Risk weights	8.127***	8.652***	8.601***	8.250***	8.076***
	(0.795)	(0.799)	(0.807)	(0.819)	(0.797)
Swap rates	0.333***	0.305***	0.297***	0.296***	0.316***
	(0.106)	(0.101)	(0.101)	(0.103)	(0.104)
High LTV	0.596***	0.558***	0.567***	0.600***	0.608***
	(0.079)	(0.077)	(0.077)	(0.080)	(0.079)
Variable rate	-0.087	-0.083	-0.065	-0.044	-0.067
	(0.079)	(0.073)	(0.072)	(0.078)	(0.079)
Fix 5 years	0.217***	0.227***	0.231***	0.233***	0.220***
	(0.077)	(0.074)	(0.075)	(0.078)	(0.077)
Time f.e.	Yes	Yes	Yes	Yes	Yes
Region f.e.	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes	Yes
Marginal cost (mean)	2.33	2.33	2.33	2.33	2.33
F statistic		21.19	9.66	6.73	22.40
Adjusted R^2	0.81	0.72	0.72	0.69	0.71
Observations	12,489	12,489	12,489	12,489	12,489

Note: The dependent variable is the marginal cost of lending. FLS outstanding dummy is a variable equal to one in the post FLS period for lenders with a positive outstanding amount of FLS borrowing. FLS outstanding log is equal to the logarithm of the outstanding amount of FLS borrowing interacted with a dummy equal to one in the post period. Lending growth >0 is a dummy equal to one in the post FLS period for lenders with a positive lending growth since the start of FLS. Reduction in marginal costs is a the reduction of marginal costs as a result of different lending growth since the start of FLS: 1.25% (125 basis points) if lending growth is > 5%; 0 if lending growth < -5% and 0.75% (75 basis points) otherwise. The excluded instrument is the fraction of asset abroad from the bank balance sheet before the FLS interacted with a dummy equal to one is the post FLS period.