Mortgage Pricing and Monetary Policy*

Matteo Benetton[¶] Alessandro Gavazza[§] Paolo Surico[‡]

June 2024

Abstract

This paper provides novel evidence on lenders' mortgage pricing and how central bank policies affected it. Using the universe of mortgages originated in the UK, we show that lenders seek to price discriminate across heterogeneous borrowers by offering menus of two-part tariffs composed of interest rates and origination fees, and that during recent periods of unconventional monetary policy, such as the UK's Funding for Lending Scheme, lenders decreased interest rates and increased origination fees. To understand lenders' pricing strategies and their effects on market equilibrium, we develop and estimate a discrete-continuous model of mortgage demand and lender competition in which borrowers may have different sensitivities to rates and fees. We use the estimated model to decompose the effects of unconventional monetary policies on mortgage market outcomes, and find that central bank policies boosted aggregate mortgage lending. Moreover, although origination fees allow lenders to price discriminate and capture surplus, banning fees would decrease aggregate mortgage lending.

*We are grateful to the Editor (Liran Einav), the Co-Editor (Emi Nakamura), three anonymous referees, Vladimir Asriyan, Giulia Brancaccio, Greg Buchak, James Cloyne, Olivier Darmouni, Daniel Greenwald, Sinem Hacioglu, Mike Joyce, Tarun Ramadorai, and several seminar participants for helpful comments. Jamie Coen provided excellent research assistance. The views expressed are those of the authors and do not necessarily reflect the views of the Bank of England, the Monetary Policy Committee, the Financial Policy Committee or the Prudential Regulatory Authority. The paper uses Financial Conduct Authority (FCA) Product Sales Data and Moneyfacts data that have been provided to the Bank of England under data-sharing agreements. The research was carried out as part of the One Bank Research Agenda. Alessandro Gavazza and Paolo Surico gratefully acknowledge financial support from the European Research Council under the Grant Agreements No. 771004 and 771976, respectively.

[¶]Haas School of Business, University of California, Berkeley. Email: benetton@berkeley.edu.

[§]London School of Economics. Email: a.gavazza@lse.ac.uk.

[‡]London Business School and CEPR. Email: psurico@london.edu.

1 Introduction

In the aftermath of the 2007–09 financial crisis, central banks around the world sought to offset the recessionary effects of the shock by cutting their policy rates and by designing new, unconventional policies, including those that acted through credit and housing markets: the US Federal Reserve QE1 and QE3, the European Central Bank (ECB) Targeted Longer-Term Refinancing Operations, and the Bank of England Funding for Lending Scheme, among others. The main goal of these unconventional policies was to make it cheaper for lenders to access funds and, in turn, "enhance the functioning of the monetary policy transmission mechanism by supporting lending to the real economy" (ECB press release, 5 June 2014).

Stimulating lending activities can be a powerful way to support the housing sector and foster consumer spending. However, several frictions in mortgage markets could alter the transmission of monetary policy to credit markets and the real economy. These include product design (Agarwal, Amromin, Ben-David, Chomsisengphet, Piskorski, and Seru, 2017; Agarwal, Chomsisengphet, Mahoney, and Stroebel, 2017; Greenwald, 2018); fixed versus adjustable-rate contracts (Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao, 2017); and lender market power (Scharfstein and Sunderam, 2016; Xiao, 2020).

The goal of this paper is to advance our understanding of the effects of central bank policies on credit markets by studying the UK residential mortgage market around the introduction of the Bank of England Funding for Lending Scheme (FLS), a central bank facility that offered cheap medium-term loans to UK lenders. A key contribution of our paper is our examination of a novel channel that affects the transmission of central bank policies to aggregate lending through heterogeneous households: lenders' indirect price discrimination strategies through menus of two-part tariffs composed of origination fees and interest rates.

Our analysis combines different data sources in order to gain a broad picture of UK mortgage markets, and critically includes loan-level data on the universe of residential mortgages originated around the onset of the FLS, as well as lenders' drawings on FLS funds. These data allow us to describe some notable institutional features of the UK mortgage market, such as posted rates and fees, and mortgages with fixed interest rates for a relatively short (e.g., 2 years) period only, which encourage borrowers to remortgage frequently.

These rich data allow us to provide new evidence on lenders' pricing strategies, most notably their pervasive use of menus of two-part tariffs that combine origination fees and interest rates. The pricing literature shows that indirect (i.e., second-degree) price discrimination through menus of two-part tariffs allows sellers to segment heterogeneous buyers and

extract surplus from them (Wilson, 1993). In the mortgage market, lenders observe some of this heterogeneity, but they may not be able (or do not want, e.g., as in Rotemberg, 2011) to directly condition their prices on observable demographic characteristics, such as income, age, or geographic region. However, this heterogeneity leads different borrowers to select different loan amounts, and thus menus of two-part tariffs effectively allow lenders to price discriminate by offering nonlinear prices and quantity discounts.

Our descriptive analysis also reveals that after the introduction of FLS, which decreased their funding costs, lenders decreased interest rates but increased origination fees. We further report some suggestive evidence that borrowers may be paying more attention to interest rates than to fees in their mortgage choices.

This evidence motivates us to understand how borrowers choose among the menus of mortgage products available, and how lenders set their rates and fees depending on their funding costs. To this end, we develop an equilibrium model of the mortgage market that incorporates the main features our descriptive analysis uncovers and estimate it using our rich datasets. On the demand side, heterogeneous borrowers make a discrete choice of their optimal mortgage product and a continuous choice of their optimal loan amount. On the supply side, differentiated lenders offer mortgage products and maximize expected profits by posting two-part tariffs consisting of interest rates and origination fees. Moroever, we allow lenders' costs of providing mortgages to depend on the characteristics of their borrowers to account for adverse selection effects on default rates (Einav, Finkelstein, and Mahoney, 2021). Central bank policies affect lenders' costs and, through them, lenders' pricing.

The estimation of demand suffers from traditional endogeneity concerns arising from the simultaneity of the discrete-continuous choice and from omitted variables correlated with the endogenous prices. To address these issues, we exploit our individual loan-level data to estimate the joint likelihood of the discrete-continuous problem with a rich set of product-market fixed effects that fully account for selection and endogeneity in mortgage pricing. This joint likelihood, along with cost shifters due to risk weights and capital requirements, following the insightful papers of Benetton (2021) and Robles-Garcia (2022), allows us to estimate borrowers' sensitivities to interest rates and fees, among other parameters.

Our demand estimates point to a large heterogeneity in borrowers' sensitivity to interest rates and origination fees. On average, borrowers appear more sensitive to interest rates than to origination fees, most notably lower-income and younger first-time buyers. Moreover, the discrete product choice demand is more elastic to interest rates than the continuous-choice loan demand. Overall, the demand parameters suggest that borrowers may be shopping

across lenders and across products for low interest rates focusing less on origination fees.

With these demand parameters, our model of lender pricing enables us to recover lenders' (unobserved) costs of supplying mortgages, which we then regress on measures of lenders' drawings on FLS funds to estimate the effect of the FLS on lenders' marginal costs. This approach allows us to exploit within-lender variation over time to identify the effects of the FLS on lenders' costs, thus flexibly controlling for several concurrent aggregate factors—most notably developments in the euro area—that could affect the funding costs of UK lenders (Churm, Joyce, Kapetanios, and Theodoridis, 2021).[1]

Nevertheless, the identification of the effect of the FLS on lenders' costs still faces one main challenge. Lenders' decisions to draw on FLS funds could be correlated with potentially unobservable time-varying determinants of their marginal costs. For example, lenders that otherwise would have high unobservable determinants of funding costs have stronger incentives to use FLS facilities. To address this endogeneity concern, we implement an instrumental variable approach that exploits the FLS design, thereby following the intention-to-treat literature (Imbens and Angrist, 1994). Specifically, we use lenders' FLS initial borrowing allowance as an instrument for their use of FLS facilities: Each bank could borrow an initial amount of up to five percent of its stock of existing loans (as of June 2012) to the real economy (Churm, Radia, Leake, Srinivasan, and Whisker, 2012).

Our IV estimates suggest that the FLS led to a reduction in lenders' funding costs by approximately 32–47 basis points (bps). Given an average marginal cost of approximately 350 bps in the quarters before the introduction of the FLS, the FLS decreases marginal costs by approximately 9–13 percent. Our estimated magnitudes fit within the range of estimates that Churm, Joyce, Kapetanios, and Theodoridis (2021) obtain using methodologies based on credit default swaps and unsecured bond spreads data of UK lenders. Moreover, our supply estimates suggest minimal or no adverse selection in this market.

We use our equilibrium model, evaluated at the estimated parameters, to decompose the overall surplus increase due to the decrease in lenders' funding costs through the FLS program between lenders and borrowers. Our parameterized model implies that lenders decreased posted interest rates by approximately 45 bps, but increased posted fees by approximately £200. These changes are consistent with our descriptive evidence, suggesting that our model includes the economic forces that account for them. More substantively, our model implies

[1]For example, many commentators argue that ECB President Mario Draghi's speech on July 26, 2012, in which he said "the ECB is ready to do whatever it takes to preserve the euro," boosted confidence in the euro area and reduced concerns about "tail" risks in financial markets (Alcaraz, Claessens, Cuadra, Marques-Ibanez, and Sapriza, 2019).

that the FLS boosted aggregate lending by more than 20 percent. We also perform an extensive analysis of the outcomes across different demographic groups, which allows us to understand the implications of the large heterogeneity across groups that we uncover. We find that households in areas with higher house prices (and thus higher loan sizes), such as London and South East England, increased their mortgage borrowing the most.

Finally, we use our model to understand the contribution of indirect price discrimination through two-part tariffs to market outcomes by banning lenders from charging origination fees. In such a counterfactual market, lenders charge higher interest rates to offset the drop in revenues due to the ban on fees. Hence, borrowing costs (i.e., rates and fees combined) increase for some groups and decline for others, with borrowers with larger mortgage loans suffering the largest rate hikes when fees are banned, because they chose products with lower rates and higher fees in the baseline economy in which lenders charge fees. Moreover, because our estimates reveal a large heterogeneity in borrowers' sensitivity to interest rates and origination fees, different borrowers respond differentially to the decrease in fees and the increase in rates due to the ban on fees. In general, borrowers with the largest loans decrease their loan sizes the most, because, on average, they suffer the largest rate hikes. Overall, the net effect is a decline in aggregate borrowing, although some groups increase their mortgage borrowing in the counterfactual economy with no fees.

Crucially for our research question of understanding the effects of central bank operations on market outcomes, these results mean that the effects of monetary policy on aggregate mortgage lending would have been smaller if lenders' price discrimination strategies through menus of two-part tariffs were simultaneously banned, and also point to some redistributive effects across heterogeneous households.

The remainder of the article is organized as follows. Section 2 highlights our main contributions and relates them to prior literature. Section 3 describes the data sources and provides descriptive evidence on the UK residential mortgage market. In Section 4, we develop a structural model of mortgage credit demand and supply, which is affected by central bank's facilities. Section 5 describes our estimation approach and the identification strategy. Section 6 presents our estimation results. In Section 7, we perform counterfactual analyses. Section 8 concludes. In the Appendices, we provide more details on our estimation dataset, institutional background, additional descriptive evidence, some model derivations, and further results of the estimated model.

2 Related Literature

This paper contributes to several strands of the literature. First, several papers study the aggregate and distributional impact of policy interventions introduced in the aftermath of the financial crisis in credit markets, with a focus on US mortgage markets. Among these, Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao (2017) study the effect of the reduction of the Federal Reserve policy rate on mortgage borrowers' leverage, and Di Maggio, Kermani, and Palmer (2020) analyze the transmission of large-scale asset purchases by the Federal Reserve to borrowers' refinancing propensity. Particularly related to our paper is Buchak, Matvos, Piskorski, and Seru (2024), who build a model of competition between banks and shadow banks in US mortgage markets to examine the effects of quantitative easing. Our paper shares with that of Buchak, Matvos, Piskorski, and Seru (2024) the attention to lender competition with heterogeneous borrowers. However, we tailor our model to the UK mortgage market (in which shadow banks and securitization play a minor role) and use it to study the effects of the Bank of England's unconventional monetary policy on market equilibrium, with a special focus on the structure of mortgage pricing.

Second, understanding consumers' and lenders' behaviors in mortgage markets and, more generally, in retail financial markets has been an important topic in economics in recent years. Several papers examine borrowers' choices and documented limited search, mistakes, and inertia (e.g., Agarwal, Ben-David, and Yao, 2017; Andersen, Campbell, Nielsen, and Ramadorai, 2020; Belgibayeva, Bono, Bracke, Cocco, and Majer, 2020; Woodward and Hall, 2012). Other papers study adverse selection by exploiting rich micro data on borrowers' choices and ex-post outcomes, such as default (e.g., Adams, Einav, and Levin, 2009; Crawford, Pavanini, and Schivardi, 2018; Cuesta and Sepúlveda, 2021; Einav, Jenkins, and Levin, 2012; Nelson, 2023). Other papers demonstrate how lenders may gain from borrowers' limited financial sophistication (e.g., Gurun, Matvos, and Seru, 2016) or how different lenders specialize in different segments of the market (e.g., Buchak, Matvos, Piskorski, and Seru, 2018). Benetton (2021) and Robles-Garcia (2022) develop and estimate equilibrium models of the UK mortgage market to study the effects of lenders' capital regulations and those of brokers, respectively, on market outcomes.[2] Our equilibrium model builds on Benetton (2021) and Robles-Garcia (2022), and we use it to study borrowers' choices and lenders' two-part pricing when central bank policies affect lenders' funding costs. In doing so, we contribute to an emerging literature that estimate equilibrium models of retail financial markets, such

[2] Liu (2019) examines how fees affect UK borrowers' mortgage costs.

as Mexican private pension markets (Hastings, Hortaçsu, and Syverson, 2017); Canadian mortgage markets (Allen, Clark, and Houde, 2019); US car loan markets (Einav, Jenkins, and Levin, 2012; Grunewald, Lanning, Low, and Salz, 2020); and US retail deposit markets (Aguirregabiria, Clark, and Wang, 2019; Egan, Hortaçsu, and Matvos, 2017), among others.

Finally, our paper also contributes to the empirical literature on price discrimination. Crawford, Shcherbakov, and Shum (2019), Leslie (2004), and Verboven (2002) examine product versioning through goods with different qualities. McManus (2007) considers nonlinear prices using a menu of goods with different fixed quantities. In this strand of literature, the papers on two-part pricing in the telecommunication markets are the closest to our setting (e.g., Economides, Seim, and Viard, 2008; Grubb and Osborne, 2015; Luo, Perrigne, and Vuong, 2018; Miravete, 2002). Our paper differs from these papers on telecommunication markets in terms of focus, because we study how central bank policies that affect lenders' costs affect their price discrimination strategies. Moreover, as we describe in Section 3, UK mortgage markets likely exhibit greater product differentiation than telecommunication markets, which prompts us to feature these non-price characteristics more prominently in our empirical model than in these studies on telecommunication markets.[3]

3 Data and Descriptive Patterns

Our analysis exploits a rich database on UK mortgage originations during the period 2010–2014. We complement our main database on mortgage originations with additional data on UK mortgage markets, lenders and their use of FLS facilities, and households' tenancy status. We now describe our datasets.

Product Sales Database. The Product Sales Database (henceforth PSD), collected by the Financial Conduct Authority (henceforth FCA), contains data on mortgage originations. For each new mortgage originated (subject to some omissions explained below), it provides the following information: loan amount, interest rate, lender, loan-to-value (LTV) ratio, interest-rate type (2-year fixed, 5-year fixed, and variable are the most common), and maturity; the main borrower characteristics: age, income, and borrower type (first-time-buyer, home-mover, or remortgager); and property characteristics: location and transaction price.

[3]Additional differences between telecommunication markets and mortgage markets are: (1) Product/tariff choice and quantity/usage choice are simultaneous in mortgage markets, whereas they are sequential in telecommunication markets. (2) Telecommunication markets feature periodic subscription contracts, whereas mortgage markets feature one-off choices, and thus have differential roles for consumer learning. (3) Adverse selection concerns may be more limited in telecommunication markets than in mortgage markets.

Different waves of PSD exist, as the reporting requirements have changed over time. The specific PSD for our period of interest 2010–2014 is PSD 001.

Despite its richness, PSD 001 has a few limitations for our purposes. First, PSD 001 has limited coverage of remortgagers. As Belgibayeva, Bono, Bracke, Cocco, and Majer (2020) describe, it does not report loans remortgaged internally, that is refinanced with the same bank that originated the previous loan. This limitation prompt us to focus on originations by first-time buyers and home movers. We note that lenders segment the markets of these two types of borrowers, offering products and setting prices specific to each type.

Second, PSD 001 does not report ex-post performances of mortgages, such as arrears and defaults. Thus, our model includes ex-ante, expected costs for arrears or defaults, but we will not be able to measure the difference between their expectation and their realization.

Third, the PSD does not report declined mortgage applications and borrowers' choice sets—for example, some mortgage products may be unavailable in some markets because lenders do not serve them. We address this issue by exploiting the choice of borrowers with similar observable demographic characteristics to construct the choice set of each borrower. Hence, we define a market as a combination of a geographic area (five areas: London, Southern England, Central England, Northern England, and Wales and Scotland), borrower type (first-time buyers or home movers), and demographic characteristics (four categories based on income and age, below and above their respective aggregate medians), yielding a total of 40 markets. We assume that a mortgage product is not available to a borrower if no other borrower in the same market and in the same quarter has chosen it.[4] Moreover, to account for differences among borrowers within the same group in terms of unobservable characteristics, such as wealth, we restrict the discrete LTV band choice to the maximum loan-to-value band just above and just below the band 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 LTV constraints.

Fourth, PSD 001 does not report mortgage fees.[5] We are able to overcome this limitation because PSD 001 reports the main product attributes of each origination, such as the borrower type (first-time buyer or home mover), lender, LTV, interest-rate type, and interest rate, which allow us to recover the origination fees by matching each PSD mortgage to the corresponding mortgage product from the Moneyfacts dataset described below. More precisely, Cloyne, Huber, Ilzetzki, and Kleven (2019), Benetton (2021), and Robles-Garcia (2022) establish that the UK mortgage market features differentiated mortgage products and

[4]Geographic area and borrower type account for almost all the variation in choice sets across borrowers.
[5]Later waves of PSD report fees from 2015, which is after the introduction of the FLS in 2012.

posted prices at the national level.[6] Hence, we define a product type as a combination of three non-price attributes: (1) lender; (2) interest rate type with fixation period; and (3) LTV ratio band. We define a product as the combination of a product type and a pair of associated rate/fee. Given a product type and an interest rate observed in PSD 001, we can recover the corresponding origination fee in the Moneyfacts dataset. Appendix A reports more details on the merging of these two datasets and the imputation of fees, as well as other missing attributes, in the PSD.

Moneyfacts. The Moneyfacts Residential Mortgage Analyzer Moneyfacts.co.uk reports the near universe of mortgage products offered in the UK, with their main attributes: the lender, the LTV band, the borrower type (i.e., first-time buyer, home-mover, or remortgager), rate type (fixed versus adjustable), fixation period, maturity, initial interest rate, and the origination fee.

FLS and Lenders' Balance Sheet Data. The Bank of England and the UK Treasury launched the FLS in July 2012 with the goal of encouraging banks and building societies to expand their lending to households and private nonfinancial corporations. The FLS offered funds to lenders at cheaper rates than those prevailing in wholesale markets, and relied on lenders to pass these lower funding costs to borrowers by lowering interest rates on loans and mortgages. Appendix B provides institutional details on the FLS, including on how the costs and the maximum available quantity of FLS funds varied across banks depending on their lending before and after its introduction. The scope of the FLS program narrowed over time and, since February 2014, focused on lending to small and medium enterprises only.[7]

The Bank of England publishes quarterly data on the initial allowance, the drawing amount, and the net flows of lending of each banking group participating in the scheme. We further complement these FLS data with quarterly data on lenders' balance sheets.

[6]Borrower-specific pricing, which is common in the US mortgage market, is extremely limited in the UK market. Moreover, lenders post identical prices across regions. Thus, 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 in our PSD sample.

[7]In response to the economic crisis triggered by the global pandemic of 2020, the Bank of England launched a funding scheme similar to the FLS, and similar schemes also opened in Australia, New Zealand, Saudi Arabia, Sweden, Taiwan, and the US. These facilities joined the existing Bank of England Term Funding Scheme, Bank of Japan Stimulating Bank Lending Facility, and European Central Bank Targeted Longer-Term Refinancing Operations. All these programs share the main goal of encouraging financial institutions to lend to households, small businesses, and corporations.

Bank of England Housing Survey. This is a public biannual household survey commissioned by the Bank of England. The purpose of the survey is to gather data on households' finances and their expectations regarding their financial future and the wider economy. We focus on questions about household demographics, current home ownership status, and expected home ownership.

3.1 Facts about UK Mortgage Markets

The goal of this subsection is to use our rich datasets to document the main patterns with respect to how UK lenders design their menus of mortgage products and price them to account for the traditional risks of mortgage lending (i.e., default and interest-rate risks), as well as to segment the market. Moreover, we document some relevant observable heterogeneity across borrowers' characteristics and mortgage choices, which are the key drivers of the reported pricing patterns. We pay special attention to two-part tariffs composed of origination fees and interest rates: We provide descriptive evidence that suggests that the main role of menus of two-part tariffs is to segment heterogeneous borrowers with respect to their mortgage sizes (i.e., their quantity), thereby implementing nonlinear price schedules and quantity discounts (Varian, 1989; Wilson, 1993; Oren, 2012).

These data also allow us to describe some institutional features of UK mortgage markets, such as posted rates and fees that do not vary across borrowers, mortgages with fixed interest rates for a relatively short (e.g., two years) time only, and recurring borrower remortgaging.

(1) A Large Number of Mortgage Products. The Moneyfacts data are particularly well suited for illustrating the richness of the mortgage products UK lenders offer to first-time buyers and home movers. Table 1 reports some interesting statistics to this end. Because lenders treat first-time buyers and home movers as separate market segments, offering slightly different mortgage products in each segment, Panel A reports statistics on product offerings for first-time buyers and Panel B for home movers.

The first row of Panel A and of Panel B reveals that in a typical month, more than 600 residential mortgage products are on offer in the UK. We emphasize that lenders offer (almost) identical menus in all UK regions they serve, hence this large number of products is not an artifact of the duplication of products across regions, though of course some small lenders have a regional reach only.

The second row of each panel reports that the number of product types per month equals approximately 200 (we remind readers that we define a product as the combination

Table 1: Product Offerings from Moneyfacts

	Mean	SD	Median	p10	p90
Panel A: First-time buyers					
Products by month (#)	636.66	105.63	628.00	494.00	790.00
Product types by month (#)	195.80	25.00	196.00	158.00	231.00
Products by type/month (#)	3.25	3.10	2.00	1.00	7.00
Lenders by month (#)	10.92	0.28	11.00	11.00	11.00
Products by lender/month (#)	58.33	43.35	45.00	19.00	111.00
Product types by lender/month (#)	17.94	4.78	18.00	12.00	25.00
Rate	3.95	1.11	3.84	2.59	5.49
Fee	679.55	561.72	499.00	0.00	1494.00
Panel B: Home movers					
Products by month (#)	610.63	109.90	600.00	466.00	784.00
Product types by month (#)	194.83	25.57	196.00	156.00	230.00
Products by type/month (#)	3.13	2.86	2.00	1.00	7.00
Lenders by month (#)	10.92	0.28	11.00	11.00	11.00
Products by lender/month (#)	55.94	40.42	45.00	19.00	101.00
Product types by lender/month (#)	17.85	4.76	18.00	12.00	25.00
Rate	3.90	1.09	3.79	2.59	5.39
Fee	723.52	561.36	795.00	0.00	1495.00

Notes—Summary statistics of the main mortgage products available to first-time buyers and home movers in the Moneyfacts database during 2010–2014.

of a product type and the associated interest rate/origination fee pair). This large number of products caters to borrowers with heterogeneous preferences and budgets over mortgage non-price attributes. For example, borrowers with different expected mobility or different risk aversion may prefer different durations of their initial fixation periods, and borrowers with different wealth may choose mortgages with different maximum LTVs.

The most typical product type is a 2-year fixed mortgage, which means that borrowers face an interest rate that is fixed for two years and reverts to a higher level thereafter, called the standard variable rate. Lea (2010) and Badarinza, Campbell, and Ramadorai (2017) document that this dual-rate structure is common to many countries, due to a combination of supply and demand factors, including banking and housing markets regulatory constraints. UK lenders hold most mortgages on their balance sheets, and thus short-term fixed rates followed by variable ones reduce lenders' exposure to interest-rate and prepayment risks, in contrast to long-term fixed-rate mortgages, dominant in the US mortgage market.[8] Best,

[8]There are no agencies like the US Government Sponsored Enterprises that effectively subsidize 30-year fixed-rate mortgages and create secondary markets for mortgages and mortgage-backed securities (Acharya, Oncu, Richardson, Van Nieuwerburgh, and White, 2011).

Cloyne, Ilzetzki, and Kleven (2020), Cloyne, Huber, Ilzetzki, and Kleven (2019), Belgibayeva, Bono, Bracke, Cocco, and Majer (2020), and Fisher, Gavazza, Liu, Ramadorai, and Tripathy (2024) document that this dual-rate structure implies that approximately 70 percent of borrowers refinance exactly at the expiration of their fixation period. Hence, this frequent remortgaging activity implies that fees account for a non-trivial share of lender revenues, because most borrowers pay them every two years.[9]

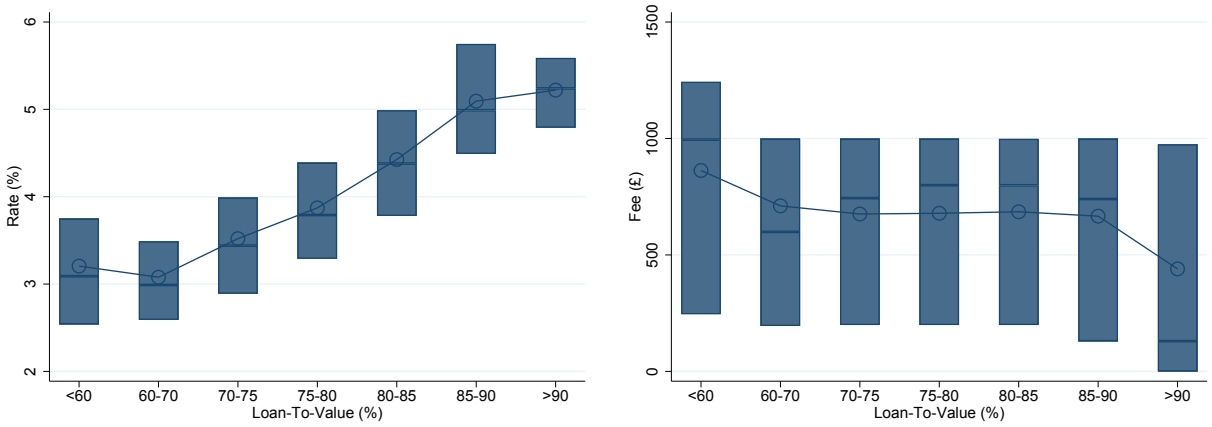
The third row of each panel reveals that the typical product type exhibits multiple fee/rate quotes—e.g., a high-fee/low-rate product and a low-fee/high-rate product. The fourth row reports that the number of lenders is stable across our sample—between 10 and 11—although at the regional level, the number of lenders is often smaller: The six largest lenders, oft-mentioned as the "Big 6," have a national presence, whereas smaller lenders, such as building societies, tend to have a narrower regional reach. On average, a lender offers approximately 60 mortgage products and 20 product types, with some lenders offering more than 100 mortgage products in a given month.

(2) Mortgage Pricing: Credit, Interest-Rate, and Prepayment Risks. Panels A and B report initial rates and origination fees, which display large variations across products. The average interest rate approximately equals 400 bps in each segment, the standard deviation approximately equals 110 bps, and the difference between the 90th and the 10th percentile of the initial interest rates approximately equals 260 bps. The average origination fee approximately equals £700, the standard deviation equals approximately £550, and the difference between the 90th and the 10th percentile is approximately £1,500. Interest rates are slightly higher in the first-time buyers segment and fees in the home movers segment.

The main driver of the variation in interest rates across products is the maximum LTV band, which is the primary way in which lenders account for borrowers' default risk. Specifically, the left panel of Figure 1 displays notable jumps in rates across mortgages with different maximum LTV bands, especially above 80 percent: mortgages with LTVs above 85 percent carry interest rates that are 200 bps higher than mortgages with LTVs below 70. This difference aligns well with the low aggregate default rates during our sample period: Mortgage arrears equal 2.34 percent of total mortgage balances in 2012Q2, the mid-point of our sample period, and declined steadily from 2010 to 2014, as we document in Appendix C. More generally, the UK has recourse mortgages, which curb borrowers' incentives to default

[9] An additional noteworthy feature of UK mortgages is that they are portable—i.e., borrowers can transfer their current mortgage products to a new property (Miles, 2004). Therefore, in principle, housing mobility does not trigger the prepayment of the loan.

Figure 1: Mortgage Pricing



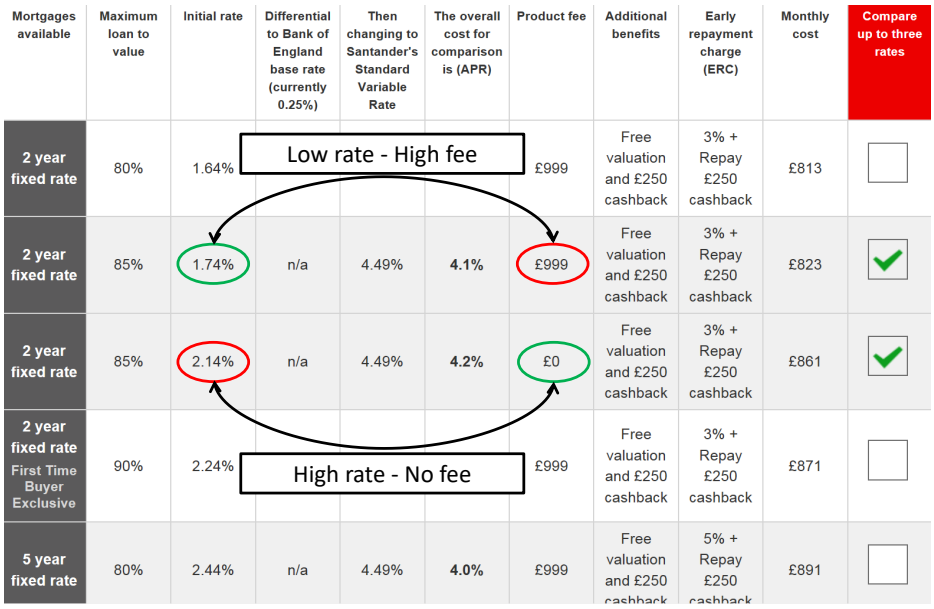
Notes—The left panel displays the average and the interquartile range of initial interest rates. The right panel displays the average and the interquartile range of origination fees for all products for first-time buyers and home movers in each LTV band in the Moneyfacts dataset during 2010–2014.

(Ghent and Kudlyak, 2011).

In Appendix C we decompose the variation in interest rates across mortgage products in the Moneyfacts dataset. The rate variation across LTV bands accounts for more than 50 percent of the residual variation after we control for aggregate changes in interest rates through monthly fixed effects. The fixation period (e.g., 2-year fixed) further captures approximately 10 percent of the rate variation across mortgage products—this is how lenders account for the interest-rate risk of their mortgage books. Moreover, rate variation across lenders accounts for approximately five percent of the total rate variation.

Finally, UK origination fees may appear similar to US mortgage points, however we believe that US points and UK fees play very different roles in their respective markets. Prepayment penalties have been banned in the US since 2008 (and many US lenders did not charge them before the ban), and thus US lenders use mortgage points to screen borrowers for their prepayment risk (Brueckner, 1994; Stanton and Wallace, 1998). UK lenders levy early-repayment penalties on fixed-rate mortgages, thereby directly charging borrowers who wish to exercise their prepayment option during the fixation period. For example, Figure 2 displays the website of a major UK lender: The early-repayment charge equals three percent on 2-year fixed mortgages and five percent on 5-year fixed mortgages. As a result of these steep charges, Cloyne, Huber, Ilzetzki, and Kleven (2019) document that very few borrowers prepay their mortgages before the expiration of their fixation period.

Figure 2: Product Definition



Notes—Snapshot from the website of a large lender on mortgages offered to first-time buyers in February 2017.

(3) The Prevalence of Two-part Pricing. Another reason for the variation in interest rates is two-part pricing. Figure 2 displays a typical example of a lender offering the same product type—i.e., a 2-year fixed term, maximum LTV of 85 percent, revert rate, additional benefits, and early repayment charges—at two distinct fee/rate quotes: a low-fee/high-rate product with a £0 fee and a 2.14 percent interest rate and a high-fee/low-rate product with a £999 fee and a 1.74 percent interest rate.

The Moneyfacts data allow us to quantify the relationship between rates and fees within a product type with the following regression:

$$r_{jkt} = \eta f_{jkt} + \chi_{kt} + \upsilon_{jkt}, \tag{1}$$

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

Table 2: Rate-Fee Relationship

	Baseline		Heterogeneity							
	(1)	(2)	(3) FTB	(4) HM	(5) LTV≤80	(6) LTV>80	(7) Big 6	(8) Small	(9) Fixed	(10) Variable
Fees (£1,000)	-0.237***	-0.281***	-0.275***	-0.288***	-0.274***	-0.298***	-0.279***	-0.283***	-0.302***	-0.208***
	(0.014)	(0.012)	(0.016)	(0.015)	(0.015)	(0.015)	(0.017)	(0.016)	(0.012)	(0.029)
R^2	0.853	0.936	0.938	0.933	0.879	0.949	0.948	0.924	0.944	0.879
No Fee	0.283***	0.337***	0.331***	0.343***	0.340***	0.329***	0.346***	0.330***	0.344***	0.312***
	(0.015)	(0.013)	(0.017)	(0.016)	(0.016)	(0.017)	(0.015)	(0.019)	(0.014)	(0.026)
R^2	0.850	0.931	0.934	0.927	0.873	0.940	0.943	0.919	0.937	0.880
Product FE	Yes	–	–	–	–	–	–	–	–	–
Time FE	Yes	–	–	–	–	–	–	–	–	–
Product-Time FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	101,185	90,305	45,987	44,318	59,651	30,654	40,520	49,785	68,249	22,056

Notes—The top panel reports the estimates from equation (1) using fees as a continuous explanatory variable. The bottom panel reports the estimates from equation (1) using an indicator variable equal to one if fees are zero, and zero otherwise, as explanatory variable. Standard errors are double clustered at the product and time level.

Table 2 reports the coefficient estimates. The top panel refers to the baseline model with continuous fees. The regression reported in the first column decomposes the product type-month fixed effects χ_{kt} into a product and a month fixed effects, thereby exploiting more observations—i.e., also those products with a single rate-fee combination per period. The regression reported in the second column uses product type-month fixed effects χ_{kt}, thereby exploiting multiple rate-fee combinations with the same non-price attributes and the same month. The second column reports that a £1,000 higher origination fee corresponds to a 28 bps lower interest rate within the same product type-quarter pair. Other columns report coefficients obtained on different subsamples of the data within the same product type-month, depending on: the market segment (first-time buyers, FTB or home movers, HM); maximum LTV (below or above 80 percent); lender (Big 6 or small); and interest-rate type (fixed or variable). The coefficients are remarkably stable across subsamples.

The bottom panel of Table 2 reports the coefficient estimates of equation (1) when we use an indicator variable equal to one for products with no fees and zero otherwise as explanatory variable. The estimates in the second column imply that lenders offer products with no fees at an interest rate that is on average 34 bps higher than identical product types but with positive fees. All estimates on different subsamples show limited heterogeneity. Appendix C.1 reports on several additional analyses on two-part pricing in our data.

(4) Borrower Heterogeneity and Two-part Pricing. We now provide some descriptive evidence about the sources of borrowers' heterogeneity that may lead lenders to use two-part pricing. We proceed in two steps. We previously described the main ways through which

lenders deal with default, interest-rate, and prepayment risks. The first step of this analysis suggests that it is unlikely that two-part pricing is an additional tool for lenders to manage mortgage risks (see also Liu, 2019). In the second step, we argue that lenders use two-part pricing to price discriminate across borrowers with heterogeneous loan amounts.

We report three pieces of negative evidence on the link between two-part pricing and mortgage risks. We focus on default risk because, as we recount above, UK short-term fixed-rate mortgages reduce lenders' concerns about interest-rate and prepayment risks, and lenders' pricing of their mortgage products compensates them for their exposure to these risks during the fixation period.

First, the right panel of Figure 1 shows that origination fees exhibit almost no variation across LTV bands, in stark contrast to the interest rates displayed in the left panel. Because default risk and loss given default increase with borrowers' leverage, Figure 1 suggests that fees are not the key pricing tool to compensate lenders for ex-ante default risk.

Second, if lenders construct menus of different rate-fee quotes to screen borrowers ex-ante based on their default risk, we might expect the number of quotes to be higher at higher LTV bands, that is the segment of the market with higher default rates. However, Appendix C reports that we do not observe a larger number of rate-fee quotes and thus finer screening through two-part pricing at higher LTV products—probably, the opposite.

Third, even if the number of products is approximately the same, lenders could still set a different rate-fee trade-off for products with high LTVs than those with low LTVs to differentially screen risky borrowers at different LTV bands. For example, riskier borrowers may be more likely to choose zero-fee products than safer borrowers because, in anticipation of their future default, risky borrowers may be less willing to pay upfront fees to reduce their future interest payments than safer borrowers. In this case, lenders should charge a larger interest rate differential between zero-fee products and positive-fee products on high-LTV mortgages than on low-LTV mortgages. However, the regressions in columns (5) and (6) of Table 2 do not find significant differences in the rate-fee trade-off between low- and high-LTV products. Similarly, Appendix C reports additional evidence that the interest rate differential between low- and high-fee products across LTV bands is negligible.

With this negative evidence in mind, we now provide some positive evidence on lenders' use of menus of two-part tariffs to price discriminate across borrowers with heterogeneous loan sizes. Differential house prices across geographic markets and within geographic markets because of different house sizes are a core dimension of heterogeneity in housing markets, and they naturally map onto heterogeneous mortgage loan amounts. Indeed, the PSD data reveal

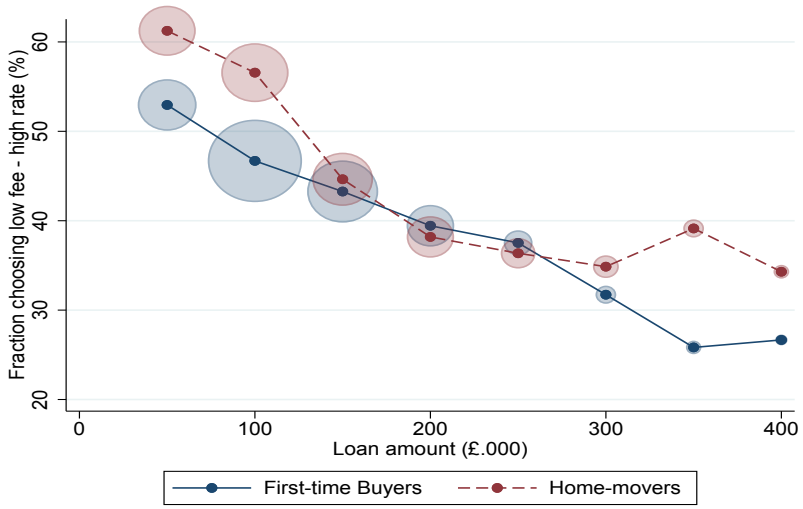
that there exists a large heterogeneity in loan amounts within all LTV bands in each market segment. Table C2 in Appendix C reports that, whereas the average loan amounts are fairly stable across LTV bands at approximately £135,000 for first-time buyers and £175,000 for home movers with an LTV of at least 70 percent, the standard deviation of loan amounts is highest for mortgages with LTVs between 75 and 80 percent in both segments, and it declines for mortgages in higher LTV bands. Hence, this large heterogeneity in loan amounts within LTV bands seems to provide a plausible reason for why lenders seek to segment the market by offering menus of two-part tariffs in each LTV band, even low ones.

When choosing between high-fee/low-rate and low-fee/high-rate products, households with larger loans most likely minimize their borrowing costs by choosing high-fee/low-rate mortgages. Consistent with this cost-minimization argument, Figure 3 shows that the fraction of borrowers who choose no-fee products declines steadily as borrowers' loan amounts increase, and the decline is similar between first-time buyers and home movers.[10] However, if borrowers were choosing products based on this cost-minimization argument only, we would perhaps expect a steeper decline than that displayed in Figure 3—i.e., almost all borrowers with the smallest loans should choose no-fee mortgages and almost all borrowers with the largest loans should choose mortgages with fees. Appendix C reports additional regression analyses of household choices of no-fee mortgage products that confirm that the loan size is negatively correlated with the choice of a no-fee product. Strikingly, once we control for loan size, the demographic characteristics available, such as age and income, are uncorrelated with such choice, thereby suggesting that selection based on observable demographics may not be a paramount feature of UK mortgage markets.

Our calculations imply that approximately 54 percent of borrowers (49 and 56 percent of first-time buyers and home movers, respectively) choose the mortgage that minimizes their borrowing costs over the fixation period when a mortgage with identical non-price attributes (e.g., same lender, LTV band, fixation period) was available; 39 percent (46 and 35 percent of first-time buyers and home movers, respectively) choose a product with a lower interest rate and a higher fee when a product with a higher interest rate and lower fee would have minimized their borrowing costs; and 7 percent (5 and 8 percent of first-time buyers and home movers, respectively) choose a product with a higher interest rate and lower fee when a product with a lower interest rate and a higher fee would have minimized

[10] Fisher, Gavazza, Liu, Ramadorai, and Tripathy (2024) show that borrowers with larger loans are more likely to refinance their mortgages at the expiration of their fixation periods than borrowers with smaller loans, because the financial gains from refinancing are larger. Thus, the choice of a high-fee/low-rate mortgage is positively correlated with the probability of refinancing, because borrowers with larger loans have stronger financial incentives to make both choices than borrowers with smaller loans.

Figure 3: Fee Choice and Loan Amounts



Notes—The figure shows the fraction of mortgages with a low fee for different loan sizes. The size of the bubble is proportional to the number of mortgages in each set.

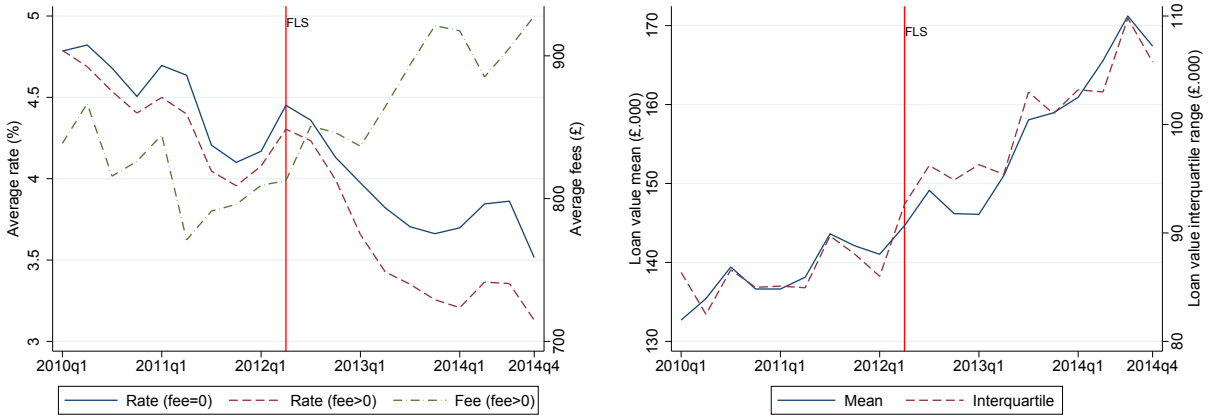
their borrowing costs. These non-cost-minimizing choices, on average, increase borrowers' costs by approximately £1,000 over the fixation period. The asymmetry in borrowers' non-cost-minimizing choices in favor of mortgages with lower rates and higher fees suggests that interest rates may be more salient than fees for borrowers' choices.

Hence, our data do not allow us to establish the exact reasons for these choices that do not minimize borrowing costs. They may arise from borrowers' limited search, mistakes, and behavioral biases (Agarwal, Ben-David, and Yao, 2017; Woodward and Hall, 2012);[11] unobservable mortgage attributes (Gurun, Matvos, and Seru, 2016); lenders who steer some unsophisticated borrowers toward more expensive products (Guiso, Pozzi, Tsoy, Gambacorta, and Mistrulli, 2022); and the interaction between borrowers' search and lenders' application approval (Agarwal, Grigsby, Hortaçsu, Matvos, Seru, and Yao, 2024).[12] Therefore, our model will feature observable and unobservable borrower heterogeneity, as well as observable and unobservable mortgage/lender attributes, to flexibly capture borrowers' choice of mortgage products from lenders' menus and their sensitivities to interest rates and fees. These demand estimates will be important inputs for our evaluation of how lenders' price discrimination strategies affect the transmission of central bank policies.

[11] Liebman and Zeckhauser (2004) propose that individuals approximate complex, non-linear schedules with simpler linear ones, which they term "schmeduling."

[12] Cloyne, Huber, Ilzetzki, and Kleven (2019) note that UK lenders allow borrowers to add origination fees to the loan, and thus borrowers may perceive the pound amount of the fees as not salient relative to the interest rate. See also Liu (2019).

Figure 4: FLS and Market Outcomes



Notes—Left panel: The solid line displays the average interest rate on products for first-time buyers and home movers with no fees (left scale), the dashed line the average interest rate on products for first-time buyers and home movers with positive fees (left scale), and the dashed-dotted line the average fees on products for first-time buyers and home movers with positive fees (right scale). Right panel: The solid line shows the average loan size for first-time buyers and home movers (left scale) and the dashed line displays the interquartile range of the loan size distribution for first-time buyers and home movers in PSD 001 for 2010–2014 (right scale).

(5) Market Outcomes around the FLS. We now describe some interesting changes to mortgage rates and fees, as well as loan amounts, after the FLS introduction.

The left panel of Figure 4 displays the time series of average mortgage rates and fees around the announcement of the FLS introduction (vertical line). Mortgage rates declined by more than 100 bps over the sample period, and this decrease, which was already ongoing before the start of the FLS in July 2012, seems to have accelerated thereafter. Moreover, before the introduction of the FLS, the rates on products with positive fees (dashed line) and products with zero fees (solid line) display parallel trends, with the no-fee products associated with a higher rate than the positive-fee products. However, after the launch of the FLS, the gap between the two rates widens: The decline in interest rates is smaller for no-fee products than for positive-fee ones, with the difference in rates between the two sets of products moving from an average of about 10 bps in the first quarter of 2012 to an average of around 50 bps by the first quarter of 2014. The dashed-dotted line portrays the time-series evolution of average fees for products with positive fees only. These fees were quite stable before the introduction of the FLS, but increased by approximately £100 afterward.

The right panel of Figure 4 displays the time series of loan size statistics in the PSD data. The solid line shows that the average loan size of first-time buyers and home movers steadily increased in 2010–2014, most notably from the fourth quarter of 2012, likely driven by the

Table 3: Summary Statistics

	Mean	SD	Median	p10	p90
Panel A: Demographics					
Gross income (£, 000)	51.79	68.72	41.81	22.00	88.55
Age (years)	35.15	8.85	34.00	25.00	48.00
First-time buyers	0.44	0.50	0.00	0.00	1.00
London	0.14	0.35	0.00	0.00	1.00
South	0.30	0.46	0.00	0.00	1.00
Middle	0.18	0.39	0.00	0.00	1.00
North	0.24	0.43	0.00	0.00	1.00
Wales & Scotland	0.14	0.34	0.00	0.00	1.00
Panel B: Choice set					
Lender per market	10.14	0.77	10.00	9.00	11.00
Product per market	77.07	16.31	75.00	57.00	100.00
Panel C: Choices					
Loan amount (£, 000)	152.55	99.11	129.75	65.25	260.25
Loan-to-value	74.74	16.06	80.00	50.00	90.00
Loan-to-income	3.25	2.01	3.20	1.87	4.48
Maturity (years)	25.91	6.68	25.00	17.00	35.00
Big 6	0.78	0.41	1.00	0.00	1.00
Fixed rate	0.88	0.33	1.00	0.00	1.00
Rate	3.88	0.96	3.79	2.69	5.19
Fee	650.24	535.97	599.00	0.00	1260.00

Notes—Summary statistics for the main variables used in the estimation.

contemporaneous decline in interest rates and increase in house prices (portrayed in the left panel of Figure C3 in Appendix C). Moreover, the dashed line displays the interquartile range of the loan size distribution, which also increased rapidly during our sample period, since house prices increased at differential rates across markets, with higher rates in London and South East England than those in other areas.

In Appendix C we report on these additional trends during our sample period: (1) House prices rose, most rapidly from 2013. (2) Aggregate arrears decreased. (3) Lenders expanded their menus of mortgage products, most notably high-LTV products for first-time buyers.

3.2 Summary Statistics

Table 3 reports summary statistics for the 2011–2013 PSD data we use to estimate our model. Our sample consists of approximately 85,000 mortgages for first-time buyers and 103,000 for home movers, which correspond to a 20-percent random sample of all mortgages.[13] Panel A reports the main demographic characteristics of these borrowers. The average

[13]We reduce the size of the estimation sample to speed up the computation of the counterfactuals.

mortgage borrower has a gross annual income of approximately £52,000 and an average age of 35 years. Geographic indicator variables report the share of mortgages in each area.

Panel B of Table 3 reports statistics on borrowers' choice sets. Each choice set (the combination of product type and an associated rate/fees pair) features approximately 10 lenders and 75 products. Appendix A reports more details on the exact construction of our estimation dataset, which entails the aggregations of mortgage products with very low market shares (less than 0.1 percent).

Panel C reports statistics on borrowers' choices. The loan amount has an average of approximately £150,000 and displays considerable heterogeneity: the standard deviation equals £99,000. Some of this heterogeneity is across borrower types—first-time buyers and home movers have average loan sizes of approximately £135,000 and £175,000, respectively—but there is sizable heterogeneity within each segment. The average loan has an LTV of 75 (82 among first-time buyers and 69 among home movers), a loan-to-income of 3.25, and a maturity of 26 years. Big 6 lenders originate more than 78 percent of mortgages. The average initial rate is 388 bps, and the heterogeneity of interest rates is quite high—the standard deviation is 96 bps—because the heterogeneity of LTVs maps onto the heterogeneity of interest rates, as Figure 1 shows. Average origination fees amount to £650.

Overall, our datasets allow us to provide a thorough description of UK mortgage markets. Market features, such as mortgage products with posted prices, prompt us to develop a discrete-choice model in which lenders offer differentiated mortgage products and heterogeneous households choose among them. Moreover, the menus of two-part tariffs with rate-fee pairs suggest that lenders actively seek to price discriminate across borrowers with heterogeneous demands for loan amounts, implementing nonlinear price schedules and quantity discounts; hence, our model includes borrowers' quantity choice as well.

Price discrimination thorugh two-part tariffs is a novel aspect of mortgage pricing to investigate. Previous studies on mortgage markets have predominantly focused on the interest rate borrowers pay. However, origination fees represent a significant component of borrowers' costs and lenders' profits, most notably because refinancing is frequent in the UK market and thus most borrowers pay the origination fee repeatedly (Cloyne, Huber, Ilzetzki, and Kleven, 2019).[14] In turn, incorporating fees allows us to provide a more complete picture of the transmission mechanism of central bank policies on lenders and borrowers.

[14] An additional noteworthy feature is that mortgage interests for owner-occupied properties are not tax deductible in the UK.

4 A Model of the UK Mortgage Market

The pricing patterns described in the previous section raise several interesting questions. Specifically, how do borrowers choose among mortgage products with different rate-fee pairs? How does lender pricing depend on their costs and borrowers' demand? How does the FLS affect lenders' funding costs and market equilibrium? How do fees affect market outcomes?

The goal of the model we develop in this section, as well as of the counterfactual analyses of Section 7, is to enable us to provide quantitative answers to these questions in a coherent manner. Moreover, the previous descriptive analysis prompts us to model borrowers' choice of a mortgage product from lenders' menus and their loan amounts in a flexible way, thereby incorporating observable and unobservable borrower characteristics and product attributes.

4.1 Household Mortgage Demand

In each market m and quarter t, there is a set J_{mt} of mortgage products, indexed by j, and I_{mt} heterogeneous potential first-time buyers or home movers, indexed by i. First-time buyers decide to either buy a property or rent a (possibly different) property, whereby renting gives them the value of the outside option $j = 0$. Home movers decide to either buy a new property or stay in their current owned property, whereby staying in their current property gives them the value of the outside option $j = 0$.

Conditional on buying a (new) property in market m, first-time buyers and home movers simultaneously choose their mortgage product from all products available to them (discrete product choice), as well as their loan amount (continuous quantity choice), given their preferences and demographic characteristics.

The indirect utility for borrower i choosing product j in market m in quarter t is

$$V_{ijmt} = \bar{V}_{ijmt}\left(\mathbf{X}_j, r_{jmt}, f_{jmt}, B_{ijmt}, \xi_{jmt}, \mathbf{Y}_i, \zeta_i; \theta_m\right) + \varepsilon_{ijmt}, \tag{2}$$

where $\mathbf{X}_j$ is a vector of time-invariant product attributes, such as the rate type, lender, and the maximum LTV; r_{jmt} is the rate and f_{jmt} is the origination fee of product j in market m and quarter t; B_{ijmt} is the branch network of the lender offering product j in the location of household i; ξ_{jmt} captures unobservable product attributes that affect the utility of all borrowers for product j in market m and period t; $\mathbf{Y}_i$ is a vector of observed household characteristics, such as income and age; ζ_i denotes unobserved household characteristics, such as wealth, risk aversion, and housing preferences; θ_m collects the demand parameters

common to all borrowers in market m; and ε_{ijmt} is an idiosyncratic shock.

If the household chooses the outside option $j = 0$ (either renting for first-time buyers, or staying in their current owned property for home movers), it enjoys utility:

$$V_{i0mt} = \bar{V}_{i0mt}\left(\mathbf{Y}_i, \zeta_i; \theta_m\right) + \varepsilon_{i0mt}, \tag{3}$$

which depends on household characteristics $\mathbf{Y}_i$ and unobserved preferences ζ_i, as well as on the idiosyncratic shock ε_{i0mt} and parameters θ_m.

Following Benetton (2021), we allow for household-specific choice sets J_i. As we explain in Section 3, we construct this choice set by comparing other households with similar observable characteristics and imposing additional restrictions based on affordability and liquidity constraints, respectively. Household i chooses mortgage product j if it delivers the highest utility of the products available in J_i and its utility is also higher than the utility of the outside option. 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

$$s_{ijmt}(\zeta_i) = Prob(V_{ijmt} \geq V_{ij'mt},\ \forall j' \in J_i \cup \{0\}). \tag{4}$$

Given the chosen product j, the optimal loan amount q_{ijmt} follows from Roy's identity:

$$q_{ijmt} = -\frac{\frac{\partial V_{ijmt}}{\partial r_{jmt}}}{\frac{\partial V_{ijmt}}{\partial Y_i}} = q_{ijmt}\left(\mathbf{X}_j, r_{jmt}, f_{jmt}, \xi_{jmt}, \mathbf{Y}_i, \zeta_i; \theta_m\right). \tag{5}$$

Equations (4) and (5) uniquely define borrowers' product and loan demand, respectively, given their preferences and mortgage attributes. In practice, equation (5) anticipates one exclusion restriction we impose: Lenders' networks of branches B_{ijmt} affect the utility of their mortgage products—equation (4)—but not the optimal loan amount—equation (5).

4.2 Lenders' Revenues, Costs, and Pricing

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

Revenues. The majority of UK mortgages have a discounted variable or fixed rate, which reverts 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, Huber, Ilzetzki, and Kleven, 2019). We focus on revenues and pricing at origination, and leave to other research the analysis of remortgaging and associated pricing (Fisher, Gavazza, Liu, Ramadorai, and Tripathy, 2024). Hence, lenders' main revenues are the net interest income and the initial origination fee.[15]

Given the demand system and borrowers' refinancing after the initial fixation period, the flows of lender l's expected total revenues in quarter t equal

$$R_{lt}(\mathbf{r}_t, \mathbf{f}_t) = \sum_m \sum_{j \in J_{lmt}} \sum_{i \in I_{mt}} s_{ijmt} \left(\frac{f_{jmt}}{\tau_{jmt}} + r_{jmt} q_{ijmt} \right), \tag{6}$$

where $\mathbf{r}_t$ and $\mathbf{f}_t$ denote the vectors of interest rates and fees charged by all lenders on their mortgage products across markets in period t, and τ_{jt} is the length of product j's fixation period. Lender l's expected revenues in quarter t are the sum of revenues collected across markets m from all products j offered to I_{mt} borrowers in each market. Each borrower i chooses a mortgage product j with probability s_{ijmt}, which generates fee income $\frac{f_{jmt}}{\tau_{jt}}$ and interest income $r_{jmt} q_{ijmt}$. Given borrowers' refinancing at the end of the fixation period τ_{jt}, the revenue function (6) accounts for the fact that products with a shorter fixation period generate higher flow revenues from fees f_{jmt}.

Costs and FLS take-up. Lenders' mortgage business incurs three types of costs. First, mortgage underwriting includes checks on borrowers' affordability, credit history, and eligibility (e.g., with respect to loan-to-income regulation), as well as checks on the property. Hence, we assume that issuing each mortgage entails a fixed underwriting cost a_{jt}, which captures the administrative costs of processing each application for product j and quarter t.

Second, lenders have funding costs. Funding costs depend, among others, on lenders' capital structures and liabilities, which in turn are affected by banking regulation. For example, capital requirements impose a minimum of equity as a percentage of risk-weighted assets. We assume that funding costs entail constant marginal costs c_{lt}^f for each pound sterling of mortgage lending by lender l in quarter t. Lender characteristics, such as their capital ratios or deposit bases, are informative of these funding costs.

Third, mortgages are risky assets. Three types of risks are prominent in mortgage lending: prepayment risk, interest-rate risk, and default risk. As we recount in Section 3, UK

[15] If borrowers do not refinance at the expiration of the fixation period, lenders gain future revenues from the standard variable rate. We can show that accounting for these future revenues is equivalent to a modified cost of lending. Section III of the Online Appendix in Benetton (2021) presents similar derivations.

mortgages include sizable prepayment penalties during the initial fixation period, which minimize borrowers' incentives to prepay their mortgages. Hence, Cloyne, Huber, Ilzetzki, and Kleven (2019) document that prepayment is extremely rare, and early-repayment charges directly cover lenders from the realization of this risk. Thus, we focus on interest-rate and default risks. Critically, mortgage products with longer fixation periods carry higher interest-rate risk and those with higher LTV bands carry higher default risk. Thus, these mortgage attributes will allow us to proxy for these risks in the estimation of Section 5.

Moreover, a recent wave of papers emphasizes that credit markets (and insurance markets) are "selection" markets, that is markets in which households differ in how costly they are to lenders because of their heterogeneous default risks (Einav, Finkelstein, and Mahoney, 2021, provide an insightful survey). Hence, we allow the costs of different mortgage products to depend on the characteristics of borrowers who choose these products to account for adverse selection effects on default rates, though we assume that there is no direct impact of product attributes on default, often described as moral hazard in this literature. In Section 5, we describe our approach to measure these selection effects.

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

$$C_{lt}\left(\mathbf{s}_{lt}, \mathbf{q}_{lt}\right) = \sum_{m} \sum_{j \in J_{lmt}} \sum_{i \in I_{mt}} s_{ijmt} \left(\frac{a_{jt}}{\tau_{jt}} + c_{ijmt} q_{ijmt} \right), \tag{7}$$

where $\mathbf{s}_{lt}$ and $\mathbf{q}_{lt}$ denote the vectors of market shares and loan amounts, respectively, of all mortgage products offered by lender l across markets in period t. c_{ijmt} is the composite constant marginal cost of lending one pound sterling of mortgage product j in quarter t to borrower i in market m, which includes funding costs c_{lt}^{f}, as well as the expected cost due to interest-rate risk and the expected cost of default of borrower i. Moreover, we adjust the underwriting costs for the fixation periods τ_{jt} in the cost function (7), as we did in the case of origination fees f_{jmt} in the revenue function (6).

The introduction of the FLS potentially changes lenders' funding costs, as they can access FLS facilities. We model this new funding option parsimoniously. Specifically, a simple revealed-preference argument implies that lenders use the optional FLS facilities to reduce their total funding costs. With some additional mild assumptions on lenders' other liabilities, FLS funds should also reduce the marginal funding costs of lenders who choose to

access them.[16] More formally, marginal funding costs c_{lt}^f satisfy

$$c_{lt}^f \leq c_{lt}^{\prime f} \qquad \text{if } Q_{lt}^{FLS} > 0, \tag{8}$$

where $c_{lt}^{\prime f}$ denote the marginal funding costs lender l would have incurred had it not used FLS facilities, and Q_{lt}^{FLS} denotes the amount lender l borrowed from the FLS facilities.

Mortgage Pricing. Given the revenues and costs specified above, lenders choose rates and fees to maximize their expected flow profits:

$$\max_{\mathbf{r}_{lt},\mathbf{f}_{lt}} \Pi_{lt}(\mathbf{r}_t, \mathbf{f}_t) = R_{lt}(\mathbf{r}_t, \mathbf{f}_t) - C_{lt}\left(\mathbf{s}_{lt}(\mathbf{r}_t, \mathbf{f}_t), \mathbf{q}_{lt}(\mathbf{r}_t, \mathbf{f}_t)\right), \tag{9}$$

where $\mathbf{r}_{lt}$ and $\mathbf{f}_{lt}$ denote the vectors of rates and fees, respectively, of lender l's existing mortgage products.

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} that satisfies the following optimality condition:

$$\begin{aligned}\frac{\partial \Pi_{lt}}{\partial r_{jt}} =& \sum_m \sum_i q_{ijmt}^e + \sum_m \sum_i s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} (r_{jt} - c_{ijmt}) \\ &+ \sum_m \sum_{k \in J_{lmt}} \sum_{i \in I_{mt}} \frac{\partial s_{ikmt}}{\partial r_{jt}} \left(\frac{f_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt} - c_{ikmt}) \right) = 0,\end{aligned} \tag{10}$$

where $q_{ijmt}^e = s_{ijmt} q_{ijmt}$ is the expected loan amount of borrower i on product j, and the summations aggregate households and markets at the product level in quarter t. The first term in equation (10) 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; and the third term collects the impact of a higher rate on the choice probability for all lender l's products J_l.

Solving for the optimal interest rate yields:

$$r_{jt}^* = \overbrace{\widetilde{c}_{jt}}^{\text{Cost}} - \frac{\overbrace{\sum_m \sum_i q_{ijmt}^e}^{\text{Mark-up}}}{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}}} - \frac{\overbrace{\frac{f_{jt}^* - a_{jt}}{\tau_{jt}} \sum_m \sum_i \frac{\partial s_{ij}}{\partial r_j}}^{\text{Net Fee Income}}}{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}}} - \frac{\overbrace{\sum_m \sum_{k \neq j} \sum_i \frac{\partial s_{ikmt}}{\partial r_{jt}} \left(\frac{f_{kt}^* - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt}^* - c_{ikmt}) \right)}^{\text{Other products}}}{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}}}, \tag{11}$$

[16] Marginal costs could increase if wholesale funding becomes more expensive for lenders that access the FLS facilities, but it did not happen (Churm, Radia, Leake, Srinivasan, and Whisker, 2012).

where

$$\widetilde{c}_{jt} = \frac{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}} c_{ijmt}}{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}}} \tag{12}$$

is a weighted average of borrowers' marginal costs c_{ijmt} of mortgage lending by means of product j. Hence, borrowers' selection affects lenders' costs of providing product j according to the weights $\frac{\frac{\partial q^e_{ijmt}}{\partial r_{jt}}}{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}}}$, which depend on the sensitivities of their expected demand q^e_{ijmt}.[17] Note that if there are no fees and no underwriting costs, all lenders offer only one product, borrowers make only the discrete product choice, and there are no selection concerns and thus marginal cost is constant across borrowers, then equation (11) collapses to the standard mark-up pricing formula with one price: $r^*_{jt} = c_{jt} - \frac{\sum_i s_{ijt}}{\sum_i \frac{\partial s_{ijt}}{\partial r_{jt}}}$.

Similarly, the optimal fee f_{jt} of product j satisfies

$$\begin{aligned}\frac{\partial \Pi_{lt}}{\partial f_{jt}} =& \sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}} + \sum_m \sum_i s_{ijmt} \frac{\partial q_{ijmt}}{\partial f_{jt}} (r_{jt} - c_{ijmt}) \\ &+ \sum_m \sum_{k \in J_{lmt}} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left(\frac{f_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt} - c_{ikmt}) \right) \leq 0,\end{aligned} \tag{13}$$

where the weak inequality (13) holds with equality if the fee f_{jt} is strictly positive. The first term of equation (13) shows 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 to the changes in loan amount; and 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 positive fee yields

$$\begin{aligned}\frac{f^*_{jt}}{\tau_{jt}} = & \overbrace{\frac{a_{jt}}{\tau_{jt}}}^{\text{Underwriting cost}} - \overbrace{\frac{\sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}}}^{\text{Mark-up}} - \overbrace{\frac{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial f_{jt}}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}} \left(r^*_{jt} - c_{ijmt} \right)}^{\text{Net Interest Income}} \\ & \underbrace{- \frac{\sum_m \sum_{k \neq j} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left(\frac{f^*_{kt} - a_{kt}}{\tau_k} + q_{ikmt}(r^*_{kt} - c_{ikmt}) \right)}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}}}_{\text{Other products}}.\end{aligned} \tag{14}$$

Equations (11) and (14) trace a negative relationship between the rate and the fee of each product j, consistent with the empirical evidence of Section 3. Rates and fees are substitute

[17] In turn, $\widetilde{c}_{jt} = \bar{c}_{jt} + \frac{\partial \bar{c}_{jt}}{\partial r_{jt}} \frac{\sum_m \sum_i q^e_{ijmt}}{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}}}$ where $\bar{c}_{jt} = \frac{\sum_m \sum_i c_{ijmt} q^e_{ijmt}}{\sum_m \sum_i q^e_{ijmt}}$ is the average cost of product j.

tools for lenders; their optimal setting depends on funding costs and underwriting costs, as well as on the relative elasticities of household demand with respect to each of them.

Lenders' optimal rates and fees, as well as borrowers' optimal choice of mortgage product and loan amount, characterize the equilibrium in the mortgage market.[18]

5 Estimation and Identification

In this section we describe the parametric assumptions we make to estimate the model. Moreover, we discuss the main variations in the data we exploit to identify the model parameters, as well as how we address endogeneity concerns.

5.1 Demand

Estimation. We build on Train (1986) and assume that the indirect utilities $\bar{V}_{ijmt}$ and $\bar{V}_{i0mt}$ equal

$$\bar{V}_{ijmt} = \frac{\gamma_m}{1-\psi_m}\left(Y_i - f_{jt}\right)^{1-\psi_m} + \exp(\delta_{jmt} + \zeta_i) + \lambda_m B_{ijmt}, \tag{15}$$

$$\bar{V}_{i0mt} = \frac{\gamma_m}{1-\psi_m} Y_i^{1-\psi_m} + \varphi_{mt}, \tag{16}$$

where Y_i is household income and φ_{mt} is a market-period fixed effect that captures the relative benefit of the outside option (i.e., renting for first-time buyers, staying in their currently owned property for home movers). The product fixed effects δ_{jmt} capture observed and unobserved attributes of product j in market m and quarter t as follows:

$$\delta_{jmt} = \mu_{mt} + \mu_{ml} - \alpha_m \log(r_{jt}) + \beta_m \mathbf{X}_j + \xi_{jmt}, \tag{17}$$

where μ_{mt} and μ_{ml} are quarter and lender fixed effects in market m, respectively.

Moreover, we assume that the unobservables ε_{ijmt} in equation (2) follow a generalized extreme value distribution with correlation coefficient ρ_m. This error structure generates a nested logit probability of household choice in each segment, with two nests: (1) an inside nest with all mortgage products $j \in J_i$ in market m and quarter t; and (2) an outside nest with the outside option $j = 0$. Hence, the probability $s_{ijmt|j\in J_i}(\zeta_i)$ that household i with

[18] We cannot prove the existence and the uniqueness of a pure-strategy equilibrium in our setting.

unobserved heterogeneity ζ_i chooses mortgage product j in his choice set J_i equals

$$s_{ijmt|j\in J_i}(\zeta_i) = \frac{\exp\left(\frac{\bar{V}_{ijmt}}{\rho_m}\right)}{\sum_{j'\in J_i}\exp\left(\frac{\bar{V}_{ij'mt}}{\rho_m}\right)}. \tag{18}$$

Similarly, the probability that household i chooses the outside option equals

$$s_{i0mt}(\zeta_i) = \frac{\exp\left(\bar{V}_{i0mt}\right)}{\exp\left(\bar{V}_{i0mt}\right) + \exp\left(\rho_m D_{imt}\right)}, \tag{19}$$

where

$$D_{imt} = \log\sum_{j'\in J_i}\exp\left(\frac{\bar{V}_{ijmt}}{\rho_m}\right) \tag{20}$$

is the inclusive value of buying a (new) property and taking out a mortgage. The unconditional probability $s_{ijmt}(\zeta_i)$ that household i with unobserved heterogeneity ζ_i chooses mortgage product j follows from (18) and (19):

$$s_{ijmt}(\zeta_i) = s_{ijmt|j\in J_i}(\zeta_i)\left(1 - s_{i0mt}(\zeta_i)\right). \tag{21}$$

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:

$$\log(q_{ijmt}) = \log\left(\frac{\alpha_m}{\gamma_m}\right) + \psi_m\log\left(Y_i - f_{jt}\right) - \log(r_{jt}) + \delta_{jmt} + \zeta_i. \tag{22}$$

Assuming that ζ_i follows a normal distribution with mean zero and standard deviation σ_m, the probability of the conditional loan demand is

$$f\left(\log(q_{ijmt})|j\in J_i\right) = \frac{1}{\sqrt{2\pi\sigma_m^2}}\exp\left(-\frac{\left(\log(r_{jt}q_{ijmt}) - \log\left(\frac{\alpha_m}{\gamma_m}\right) - \psi_m\log\left(Y_i - f_{jt}\right) - \delta_{jmt}\right)^2}{2\sigma_m^2}\right).$$

We proceed in two steps to estimate the demand parameters. In the first step, we construct the joint log-likelihood of observing borrowers choosing their mortgage products and loan amounts, conditional on taking out a (new) mortgage, in each of the 40 markets we defined in Section 3 as a combination of borrower type, demographic characteristics, and

geographic areas:

$$\mathcal{L}_m = \sum_t \sum_i \sum_{j \in J_i} \mathbb{I}_{ijmt} \left(\log(s_{ijmt|j \in J_i}) + \log(f(\log(q_{ijmt})|j \in J_i)) \right), \tag{23}$$

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

The log-likelihood (23) includes a set of product-market-quarter fixed effects δ_{jmt} that capture observed and unobserved product attributes, as equation (17) shows. Because Roy's identity imposes the restriction that the constant of the loan demand function (22) includes the parameter α_m, which also enters into equation (17), we maximize the log-likelihood (23) subject to the constraint that α_m satisfies equation (17). In practice, we implement this constraint imposing that α_m equals the coefficient estimate of $\log(r_{jt})$ in the IV regression (17), with the estimated product-market fixed effects as dependent variable and suitable supply-side instruments (described below) that deal with the correlation between the interest rate r_{jt} and the unobservable attribute ξ_{jmt}.

This first step yields estimates of the following parameters:

$$\tilde{\gamma}_m \equiv \frac{\gamma_m}{\rho_m}; \quad \psi_m; \quad \tilde{\lambda}_m \equiv \frac{\lambda_m}{\rho_m}; \quad \sigma_m; \quad \tilde{\delta}_{jmt} \equiv \delta_{jmt} - \log(\rho_m); \quad \alpha_m; \quad \beta_m.$$

In the second step, we obtain the nesting parameter ρ_m and the market-quarter fixed effects φ_{mt} that enter the indirect utility of the outside option (16) by estimating the binary logit probability (19) using Bank of England Household Survey data. This second step requires that we impute the inclusive value D_{imt} to each household in the survey, which we do based on the observed household characteristics (income and age) and draws of the unobserved ζ_i for renters and stayers, assuming that they have a lower average ζ_i than those of first-time buyers and and home-movers, respectively.[19] Because the survey has few observations only, we estimate one $\rho_m = \rho$ for all markets m.

Identification. Estimation of the demand parameters addresses 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 estimate the discrete and continuous choice jointly. As we explain above, the

[19] Hence, we can intepret ζ_i as a preference for homeownership or a new property, and thus for example first-time buyers have stronger preferences for ownership than renters with identical observable demographic characteristics.

local branch network enters into the discrete choice only. Specifically, we exploit variation in the branch network, along with variation in the location of borrowers' houses at the postcode level, to identify the effect of lenders' local branch networks on borrowers' choice of lenders.

Second, lenders simultaneously set interest rates and origination fees, which could be correlated with unobserved product attributes. For example, a lender could raise the interest rate and 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 this lender's products despite its higher rates and fees; hence, we would mistakenly infer that these borrowers do not respond to prices, whereas their choices depend on the lender's unobserved characteristics.

Our estimation procedure addresses the possible correlation between fees f_{jt} and unobservable attributes ξ_{jmt} by including product-market-quarter fixed effects δ_{jmt} that capture all 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 f_{jt} by the same amount—i.e., only $Y_i - f_{jt}$ matters to them, which varies across borrowers and across products. (2) Roy's identity requires that all parameters—most notably, the product-market-quarter fixed effects—that enter into discrete product demand and continuous loan demand be the same. Hence, any residual variation in the loan demand that the fixed effects δ_{jmt} do not capture and is correlated with $Y_i - f_{jt}$ 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 is correlated with $Y_i - f_{jt}$ identifies the parameter γ_m in the discrete-choice equation.

Instruments. Our estimation deals with the possible correlation between the interest rate r_{jt} and the unobservable ξ_{jmt} in regression (17) by exploiting cost shifters of the interest rate previously employed and motivated in Benetton (2021) and Robles-Garcia (2022), that is risk-weighted capital requirements.

Risk-weighted capital requirements affect lenders' cost of supplying a specific mortgage 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. The adoption of an internal model versus the standardized approach to assessing the risk of different assets and thus to calculate risk-weighted assets is correlated with bank size, which in turn can affect demand directly through convenience and brand value. Hence, in our demand estimation we include lender fixed effects among the time-invariant attributes X_j in equation (17). We can

still include lender fixed effects and use risk-weighted capital requirements as instruments because risk weights vary across products with different LTVs within lenders, and this variation across LTV is non-uniform across lenders: higher LTVs mortgages have higher risk weights for all lenders, and the difference between the risk weights on high-LTV mortgages and low-LTV mortgages is smaller for lenders using internal models than for lenders using the standardized approach, as Benetton, Eckley, Garbarino, Kirwin, and Latsi (2021) and Benetton (2021) document. In support of the exclusion restriction, Benetton (2021) (Figure 7 and Figure 4 in the Internet Appendix) shows no significant differences between lenders using internal rating-based models and lenders using the standardized approach in terms of ex-ante characteristics of their mortgage borrowers, such as their age and income, and ex-post mortgage performances, such as arrears and refinancing.

5.2 Supply

Estimation. Estimation of the supply-side parameters relies on lenders' optimal pricing, i.e., equations (11) and (14). Inverting those to recover costs is nowadays a standard procedure in most equilibrium IO models, but in our case this inversion presents a few challenges.

The first challenge is that our model features marginal costs c_{ijmt} that vary across borrowers i for the same product j, because of borrowers' heterogeneous default risks. The pricing equations (11) and (14) show that lenders' costs depend on their rates and fees, by changing the borrowers' pool. Moreover, equations (11) and (14) also indicate that borrowers' marginal costs c_{ijmt} enter into each pricing equation with different weights, complicating their aggregation at the product level. Many papers on selection in credit markets exploit individual data on ex-post delinquencies to directly measure the ex-ante expected default costs across borrowers and products (e.g., Adams, Einav, and Levin, 2009; Crawford, Pavanini, and Schivardi, 2018; Cuesta and Sepúlveda, 2021; Einav, Jenkins, and Levin, 2012; Nelson, 2023). However, as we describe in Section 3, unfortunately the PSD 001 dataset does not report individual (or product-level) mortgage delinquencies, and thus we do not have any direct information on borrower-specific costs c_{ijmt}.

Our approach to addressing this challenge builds on the insight of exploiting "unused observables" introduced by Finkelstein and Poterba (2014). Specifically, as we explain in Section 3, UK lenders post their menus of mortgage products and prices. This absence of customized prices is a pervasive (and perhaps puzzling) practice in several UK household credit and insurance markets: for example, Matcham (2023) documents it in UK credit cards. Hence, Finkelstein and Poterba (2014) test for adverse selection in UK annuities by

identifying demographic characteristics that insurance companies do not use to set prices but are correlated both with insurance demand and ex-post claims.

We adapt their insight to our setting by assuming that c_{ijmt} depends on borrowers' selection based on their observable characteristics $\mathbf{Y}_{imt}$ reported in our data (age, income, and their interaction) only. Hence, we can decompose marginal costs as follows:

$$c_{ijmt} = \hat{c}_{jt} + \omega_Y \mathbf{Y}_{imt}. \tag{24}$$

where $\hat{c}_{jt}$ capture all other costs of product j in quarter t, which depend on lender characteristics and their participation in the FLS (to capture funding costs), as well as on observable and unobservable product attributes (to capture interest-rate risks and some default costs).

Based on the decomposition of marginal cost c_{ijmt} in equation (24), we can substitute $c_{ijmt} = \hat{c}_{jt} + \omega_Y \mathbf{Y}_{imt}$ into lenders' first-order conditions for optimal prices, i.e., equations (11) and (14). With a guess of the parameter ω_Y, we can solve the system of these optimality conditions to recover the cost variable $\widetilde{c}_{jt} = \hat{c}_{jt} + \omega_Y \frac{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}} \mathbf{Y}_{imt}}{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}}}$ and the underwriting costs a_{jt} of each product j and quarter t.

However, solving the system of optimality conditions poses a second challenge. In most IO equilibrium models, the number of first-order conditions equals the number of unknown marginal costs and thus the system of equations is exactly determined. In our data, some products have zero fees and we think it is not plausible that the first-order conditions (14) hold with equality in these cases. We could choose not to include these first-order conditions in our system of equations, but their exclusions would entail an efficiency loss.

We opt to include these equations with their corresponding Lagrange multipliers ν_{jt}:

$$\frac{\partial \Pi_{lt}}{\partial f_{jt}} - \nu_{jt} = 0$$

with the constraints $\nu_{jt} \leq 0$. Hence, the inclusion of these equations allows us to exploit all the first-order conditions to recover the cost variable $\widetilde{c}_{jt}$ and underwriting costs a_{jt}. But the inclusion adds one unknown auxiliary parameter ν_{jt} for each zero-fee first-order condition, making the system of equations underdetermined. Thus, we reduce the number of unknowns by imposing that all products offered by a lender with the same LTV band in a given quarter t have the same underwriting costs a_{jt}. We end up with an overdetermined system of equations, and we choose the solution that minimizes the sum of the squared violations

of lenders' first-order conditions, subject to the constraints that the multipliers $\nu_{jt} \leq 0$.

Having recovered the cost variable $\widetilde{c}_{jt}$, we then estimate the following regression:

$$\widetilde{c}_{jt} = \omega_l + \omega_t + \omega_X \mathbf{X}_{lt} + \omega_F \mathbb{1}\{Q_{lt}^F > 0\} + \omega_X \mathbf{X}_j + \omega_Y \bar{\mathbf{Y}}_{jt} + \kappa_{jt}, \tag{25}$$

where ω_l are lender fixed effects; ω_t are quarter fixed effects; $\mathbf{X}_{lt}$ are lender characteristics; $\mathbb{1}\{Q_{lt}^F > 0\}$ is an indicator variable equal to one when lender l uses FLS funds in quarter t (defined more precisely below); $\mathbf{X}_j$ are time-invariant product attributes; $\bar{\mathbf{Y}}_{jt} = \dfrac{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}} \mathbf{Y}_{imt}}{\sum_m \sum_i \frac{\partial q^e_{ijmt}}{\partial r_{jt}}}$ are borrowers' observable demographic characteristics weighted by the sensitivity of their expected borrowing q^e_{ijmt} on product j in quarter t, as in equation (12); and κ_{jt} is the structural error term capturing unobservable determinants of costs of product j in quarter t.

We use two related definitions of the indicator variable $\mathbb{1}\{Q_{lt}^F > 0\}$ in the regression equation (25). In our main analysis, $\mathbb{1}\{Q_{lt}^F > 0\}$ equals one if lender l has a net positive drawing flow on FLS funds in quarter t, and zero otherwise. In the robusteness analyses of Appendix E, $\mathbb{1}\{Q_{lt}^F > 0\}$ equals one if lender l has a net positive drawing stock on FLS funds in quarter t, and zero otherwise. The first definition displays more variation than the second because most lenders do not access FLS facilities in every quarter. The second one recognizes that lenders may not lend out new FLS funds exactly in the same quarter they access them. Drawing FLS funds is a choice of each lender, and thus the variable $\mathbb{1}\{Q_{lt}^F > 0\}$ is endogenous. Hence, we estimate equation (25) using the instruments described below.

Finally, we compare the estimated ω_Y in equation (25) with our initial value, and iterate our procedure until they are sufficiently close. In practice, our initial value equals $\omega_Y = 0$.

Identification. The main parameter of interest in cost equation (25) is the coefficient ω^f of the indicator variable $\mathbb{1}\{Q_{lt}^F > 0\}$, which varies over time, before and after implementation of the policy, and in the cross-section during the FLS period because some lenders do not draw on new FLS funds in every quarter (in the case of our first definition), or because some lenders access the FLS later than other lenders (in the case of our second definition). Hence, we can control for lender and quarter fixed effects—thereby flexibly controlling for concurrent macro shocks that could affect the funding costs of all UK lenders—and exploit within-lender variation over time to identify the effects of the FLS on lenders' costs. Nevertheless, lenders' decision whether to draw on FLS funds could be correlated with unobservable, time-varying costs κ_{lt}. Hence, we implement an instrumental variable approach that exploits the FLS

design, thus following the intention-to-treat literature (Imbens and Angrist, 1994).

Specifically, we use lenders' FLS initial borrowing allowance as an instrument for their use of FLS facilities: Each bank could borrow an initial amount of up to five percent of its stock of existing loans (as of June 2012) to the real economy (Churm, Radia, Leake, Srinivasan, and Whisker, 2012).[20] Thus, the instrument takes a value of zero for all lenders before the introduction of the FLS, and varies across lenders after the introduction of the FLS depending on their June 2012 loan books. In practice, our instrument entails that lenders with larger allowances access FLS funds over more quarters (according to the first definition) or earlier (according to the second definition) than those with smaller allowances. Because banks face adjustment costs to their capital structure (e.g., Diamond and Rajan, 2000; Lemmon, Roberts, and Zender, 2008), lenders with larger allowances have larger incentives to incur in these costs to access FLS funds more frequently. Benetton and Fantino (2021) exploit a similar instrument to study the effects of the European Central Bank's Targeted Long-term Refinancing Operations on bank lending to firms.

6 Results

We first present parameter estimates of the demand model and implied elasticities for both interest rates and fees. We then present our estimates of the marginal cost equation, and thus the effect of lenders' participation in the FLS on their funding costs.

6.1 Demand

Table 4 collects the main demand parameters. We report the mean and standard deviation of each parameter in the population. Figure E1 in Appendix E displays the estimates and the 95-percent confidence intervals of the demand parameters in each group.

The signs of these parameters are broadly as expected, and their magnitudes and heterogeneity are often noteworthy. The parameter α_m, which measures the sensitivity to interest rates, displays substantial heterogeneity across groups; see top-left panel of Figure E1 in Appendix E. Parameters $\beta_m^{High\,LTV}$ and $\beta_m^{Fixed\,5}$ indicate that borrowers prefer mortgages with higher maximum LTV limits and fixed-rate mortgages with longer fixation periods, respectively. The parameter $\tilde{\lambda}_m$ indicates that a higher density of branches in a location has a

[20] Banks were eligible to borrow additional funding equal to their positive net lending—new lending minus repayments—while the FLS was running. We do not include this additional funding in the value of our instrument, because it may be endogenous.

Table 4: Demand Parameters

	α_m	$\beta_m^{HighLTV}$	β_m^{Fix5}	$\tilde{\lambda}_m$	ψ_m	$\tilde{\gamma}_m$	σ_m	ρ
Mean	0.22	0.09	0.02	0.02	0.22	0.02	0.43	0.02
SD	0.04	0.02	0.01	0.00	0.16	0.00	0.07	0.00

Notes—The table reports the weighted mean and standard deviation of the estimated demand parameters across groups. The weights equal the number of observations in each group.

positive effect on borrowers' product demand, though this coefficient is small. The parameter ψ_m indicates a departure from quasi-linearity in income, with substantial heterogeneity in our population. The parameter σ_m implies that unobserved heterogeneity plays a moderate role among first-time buyers, and a larger one among home movers; see bottom-right panel of Figure E1 in Appendix E. Finally, the parameter ρ indicates a small substitution between inside mortgage products and the outside option.

Appendix E displays several plots that illustrate that the model fits the data well, thus capturing the rich heterogeneity of the data.

Given that borrowers' sensitivities to rates and fees play an important role in our counterfactual analyses, in Table 5 we report the statistics of demand elasticities to the interest rate and the origination fee. Panel A reports the elasticities of the expected demand $\sum_m \sum_{i \in I_{mt}} q^e_{ijmt}$, which combines the continuous loan demand (Panel B) and the discrete product demand (Panel C). Panel A shows that, on average, borrowers are substantially more elastic to the interest rate than the origination fee. However, the elasticity with respect to the fee exhibits a larger coefficient of variation than the elasticity with respect to the interest rate. Panel B reports that, on average, a one percent increase in the interest rate leads to a 1.22 percent decrease in the loan size. Panel C reports that, on average, a one percent increase in the rate leads to a 7.42 percent decrease in market share, which is slightly higher than previous studies of UK and US mortgage markets (Benetton, 2021; Buchak, Matvos, Piskorski, and Seru, 2024). Hence, the product demand exhibits substantially higher elasticity to the interest rate than the continuous demand, whereas the elasticities with respect to the fee are more similar. These magnitudes suggest that borrowers may be shopping across lenders and products for a low interest rate, focusing less on the origination fee.

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 £1,000 increase in the origination fee in borrowers' demand functions and report it in the last row of Panel A. Overall, such an increase requires an average decrease of 18 bps, with

Table 5: Demand Elasticities to Rates and Fees

	Mean	SD	Median	p10	p90
Panel A: Expected demand					
Elasticity rate	-8.64	1.48	-8.60	-10.37	-6.78
Elasticity fee	-0.39	1.17	-0.15	-0.68	0.00
Rate decrease per £1,000 fee	-0.18	0.32	-0.08	-0.38	-0.04
Panel B: Continuous demand					
Elasticity rate	-1.22	0.02	-1.22	-1.24	-1.20
Elasticity fee	-0.38	1.16	-0.14	-0.66	0.00
Rate decrease per £1,000 fee	-0.89	1.48	-0.45	-1.84	-0.21
Panel C: Discrete demand					
Elasticity rate	-7.42	1.47	-7.38	-9.13	-5.58
Elasticity fee	-0.01	0.01	-0.01	-0.02	0.00
Rate decrease per £1,000 fee	-0.01	0.00	-0.01	-0.01	-0.01

Notes—Panel A shows the elasticity of the expected demand $\sum_m \sum_{i \in I_{mt}} q^e_{ijmt}$ with respect to the interest rate and the fee. Panel B shows the elasticity of the continuous demand $\sum_m \sum_{i \in I_{mt}} q_{ijmt}$ with respect to the interest rate and the fee. Panel C shows the elasticity of product demand $\sum_m \sum_{i \in I_{mt}} s_{ijmt}$ with respect to the interest rate and the fee. Elasticities are computed using the formulas in Appendix D. One observation corresponds to one mortgage product in a given quarter.

considerable heterogeneity across mortgage products—the 10th percentile equals 38 bps, the median 9 bps, and the 90th percentile 4 bps. Hence, the average magnitude is slightly lower than that of the empirical "exchange rate" between 28 bps and £1,000 in fees reported in Table 2, thereby corroborating that borrowers on average focus more on interest rates than on fees in their choices, and most notably in their discrete product choice, as Panel C shows. Of course, some of the heterogeneity in the sensitivity to rates and fees arises because borrowers' loan amounts differ, and thus borrowers should rationally weigh fees and interest rates differentially. Nevertheless, the magnitudes of the variations reported in Table 5 is substantially larger than those that cost-minimization arguments imply, and Appendix E reports additional calculations that corroborate this finding.

Finally, Tables E1 and E2 in Appendix E document that the demand estimates imply reasonable substitution patterns across products. Specifically, products with the largest cross-price elasticity with respect to the interest rate of a given product either have the same attributes (e.g., the same LTV band) but are offered by different lenders, or are offered by the same lender in an adjacent LTV band.

6.2 Supply

Table 6 collects coefficient estimates of equation (25). The dependent variable is the estimated cost variable $\widetilde{c}_{jt}$ and the main coefficient of interest is that of the indicator variable $\mathbb{1}\{Q_{lt}^F > 0\}$, which accounts for the effect of the FLS on lenders' costs. Table 6 reports the regressions in which $\mathbb{1}\{Q_{lt}^F > 0\}$ depends on lender l's net positive drawing flow on FLS funds in quarter t, whereas Table E3 in Appendix E reports the regressions in which $\mathbb{1}\{Q_{lt}^F > 0\}$ depends on lender l's net positive drawing stock on FLS funds in quarter t. All regressions further include lender characteristics, obtained from their balance sheets, and mortgage product attributes, as well as lender and quarter fixed effects.

Column (1) presents OLS estimates. The coefficient of $\mathbb{1}\{Q_{lt}^F > 0\}$ is negative. However, as we argued in Section 5.2, banks endogenously choose to access FLS facilities, and thus this choice can be correlated with unobservable determinants of lenders' marginal costs. Presumably, lenders with high funding costs, for observable and unobservable reasons, are exactly those that benefit the most from accessing cheap FLS funds, thereby suggesting that the OLS coefficient in column (1) may be biased towards zero.

Column (2) reports the first-stage estimates of our IV regressions. Our instruments, based on the design of the FLS, have a strong positive correlation with lenders' decision to borrow from the FLS facilities. We should point out that column (2) shows that some bank controls, most notably their bank capital ratio, play a significant role in the first stage, suggesting that worse-capitalized banks are more likely to use FLS facilities.

Column (3) reports second-stage IV estimates. They indicate that borrowing from FLS facilities reduced lenders' funding costs by 47 bps. This coefficient fits within the range of estimates that Churm, Joyce, Kapetanios, and Theodoridis (2021) obtain using methodologies based on credit default swaps and the unsecured bond spreads data of UK lenders. Given an average marginal cost of approximately 330 bps in the quarters before the introduction of the FLS, the FLS decreases marginal costs by 14 percent.

Although our main focus is on the effects of the FLS, Table 6 also reports estimates for other variables that affect lenders' costs. Mortgage products with higher risk weights have higher costs, as they increase lenders' required equity to hold mortgages on their balance sheets. Similarly, higher swap rates increase costs, because they increase the spread lenders pay to exchange the fixed interest rate for the variable benchmark. Mortgage products with higher LTVs, and thus higher expected default rates, have higher costs. Moreover, mortgages with a longer fixed rate, which carry greater interest rate risk for lenders, have higher costs; mortgages with variable rates have lower costs than those with a short-term fixed rate (the

Table 6: The FLS and Lenders' Costs

	FLS Flow					
	(1) OLS	(2) FS	(3) IV	(4) OLS	(5) FS	(6) IV
FLS						
Drawing flow > 0	-0.055**		-0.466**	-0.065***		-0.319*
	(0.025)		(0.186)	(0.024)		(0.171)
Excluded Instruments						
FLS Allowance (£)		0.026***			0.027***	
		(0.004)			(0.004)	
Lender Characteristics						
Sight deposits	-0.896	1.669***	0.347	-1.094	1.547***	-0.349
	(0.807)	(0.492)	(0.844)	(0.725)	(0.501)	(0.705)
Time deposits	-1.465*	-2.542***	-1.036	-1.679**	-2.698***	-1.422*
	(0.845)	(0.700)	(0.803)	(0.803)	(0.689)	(0.750)
Capital ratio	0.344	-5.385***	-2.174	-2.605**	-5.297***	-4.134**
	(1.350)	(0.847)	(1.715)	(1.313)	(0.957)	(1.716)
Repos	6.830***	1.930***	8.179***	4.429***	1.477**	5.203***
	(1.138)	(0.739)	(1.254)	(1.063)	(0.704)	(1.134)
Assets (£T)	-0.225	0.363	-0.379	-0.399	0.387	-0.501
	(0.379)	(0.315)	(0.333)	(0.362)	(0.332)	(0.330)
Product-level Costs						
Risk weights	5.224***	0.041	5.265***	-0.371	-0.716	-0.443
	(0.528)	(0.111)	(0.529)	(0.928)	(0.534)	(0.971)
Swap rates	0.448***	-0.130***	0.388***	0.558***	-0.169***	0.511***
	(0.072)	(0.036)	(0.079)	(0.055)	(0.047)	(0.069)
High LTV	0.696***	0.007	0.697***			
	(0.057)	(0.010)	(0.057)			
Home movers	-0.313***	-0.019	-0.322***			
	(0.046)	(0.015)	(0.047)			
Variable rate	-0.223***	-0.014*	-0.229***			
	(0.039)	(0.008)	(0.039)			
Fix 5 years	0.119**	0.068***	0.153***			
	(0.057)	(0.020)	(0.059)			
Selection						
Age	-0.013	-0.007*	-0.016*	-0.007	-0.009*	-0.009
	(0.009)	(0.004)	(0.009)	(0.007)	(0.005)	(0.007)
Income	0.577	-0.586**	0.330	0.374	-0.721**	0.188
	(0.464)	(0.246)	(0.521)	(0.375)	(0.294)	(0.432)
Age × Income	-0.008	0.016***	-0.001	-0.004	0.020***	0.001
	(0.012)	(0.006)	(0.013)	(0.010)	(0.007)	(0.011)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	No	No	No
Product f.e.	No	No	No	Yes	Yes	Yes
Marginal cost (mean)	3.17	0.21	3.17	3.16	0.21	3.17
F statistic			52.29			53.01
Adjusted R^2	0.77	0.59	0.76	0.86	0.56	0.86
Observations	2,796	2,796	2,796	2,791	2,791	2,796

Notes—The dependent variable is the cost $\widetilde{c}_{jt}$ of each mortgage product j in quarter t. Standard errors are clustered at the product level.

baseline category). Finally, products in the home mover segment have lower costs than those in the first-time buyer segment, possibly because of lower expected default costs.

Interestingly, the coefficient estimates of borrowers' demographic characteristics suggest negligible selection effects. The coefficient of the weighted average borrower income is always insignificant. The negative coefficient of the weighted average age suggests that mortgage lending to younger borrowers is more costly—according to our assumptions, because of higher expected default costs. However, its magnitude is small, suggesting minimal economic relevance: The standard deviation of the weighted average borrower age across observations equals 4.18 years, and thus the coefficient in column (3) means that a one-standard-deviation increase in the weighted average borrower age increases costs $\widetilde{c}_{jt}$ by 6.6 bps, or 8 percent of the standard deviation of the costs $\widetilde{c}_{jt}$ across observations, which equals 83 bps.

Specifications (4)–(6) replicate the regressions (1)–(3) further including product-type fixed effects. Therefore, these regressions allow us to control for all observed and unobserved product attributes that are fixed over time (hence, we cannot estimate the coefficients of the observed product attributes). These regressions confirm that the FLS decreases lenders' costs by 32 bps. Moreover, the coefficients of borrowers' observed demographic characteristics are all statistically insignificant.

Overall, the coefficients of the "unused observables" in Table 6 suggest minimal or no adverse selection in this market. Therefore, the cost variable $\widetilde{c}_{jt}$ corresponds to the marginal cost of lending by means of product j in quarter t. However, we should acknowledge that the unavailability of individual data on the ex-post mortgage performance, as well as on declined mortgage applications, does not make the PSD 001 dataset ideally suited for a thorough analysis of the effects of borrowers' selection on lenders' costs.

In Appendix E, we report on two additional sets of regressions: (1) Table E3 presents the coefficient estimates of the regression equation (25) obtained using our second definition of the indicator variable $\mathbb{1}\{Q_{lt}^F > 0\}$, that is whether lender l has a net positive drawing stock on FLS funds in quarter t. These regressions confirm that larger FLS drawings lowered lenders' funding costs more. (2) Table E4 reports similar regressions to those of Tables 6 and E3, but with the estimated underwriting cost a_{ij} as dependent variable. We do not find any evidence that the FLS program affected underwriting costs, which provides a useful placebo test of our analysis, because changes in funding costs should be orthogonal to any changes in lenders' costs of processing mortgage applications. Moreover, Tables E3 and E4 confirm that selection effects are negligible, if any.

7 Model Implications and Counterfactual Policies

In this section, we use our model evaluated at the estimated demand and supply parameters to study the equilibrium effects of: (1) the FLS; and (2) fees and two-part tariffs. Hence, the first case focuses on lenders' costs and the second on lenders' pricing.

7.1 The Effect of the FLS on Market Outcomes

Columns (1) and (2) in Table 7 report key outcomes of interest for two representative quarters, one before (2011Q3) and one after the introduction of FLS facilities (2013Q3). These outcomes correspond to the fitted values of the model evaluated at the estimated parameters in the two quarters. The top part of Table 7 reports the averages and standard deviations (in parentheses) of marginal costs and underwriting costs. These statistics place equal weight on each mortgage product. The comparison between the pre-FLS period and post-FLS period reveals that lenders' average costs declined: marginal costs by 59 bps and underwriting costs by £138.[21] The middle part reports that enders lowered their interest rates on average by 82 bps, but they increased their origination fees on average by £190 (again, these statistics weight each mortgage product equally). Moreover, the number of mortgage products also increased from 220 in the pre-FLS market to 242 in the FLS market. The bottom part of Table 7 reports that the average mortgage amount increases by approximately £23,000, or 18 percent of the 2011Q3 average loan amount, and the number of mortgages increases by approximately 4,000, or 24 percent of 2011Q3 originations.

Although the comparison between the fitted model evaluated in 2011Q3 and 2013Q3 suggests that FLS had nontrivial effects on market outcomes, we should acknowledge that the differences between markets in 2011Q3 and 2013Q3 may not exclusively be due to the availability of FLS facilities. For example, Table 7 reports that underwriting costs declined and that the number of mortgage products offered increased, whereas our model does not consider the reasons for these changes (we report on these changes in product offerings in Appendix C). Hence, we aim to isolate the effect of the FLS on market outcomes by performing a more-controlled comparison between the market in 2011Q3 and a counterfactual market in which the FLS exclusively affects lenders' funding costs.

Specifically, we reduce the marginal costs $\widetilde{c}_{jt}$ of those lenders who drew FLS funds by

[21] Plausible explanations for the decline in underwriting costs include banks' increased adoption of technology in mortgage underwriting, as Fuster, Plosser, Schnabl, and Vickery (2019) show for the US mortgage market; the increasing share of UK mortgages originated by brokers, who have lower costs than lenders (Robles-Garcia, 2022); and changes in mortgage underwriting regulation (Van Dijk and Garga, 2006).

Table 7: Effects of the FLS on Mortgage Supply and Demand

	Pre-FLS (2011Q3)	FLS data (2013Q3)		FLS model		FLS no fee model	
	Level	Level	Percent Change	Level	Percent Change	Level	Percent Change
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Costs:							
Marginal Costs (bps)	327	268	-18.16	292	-10.62	292	-10.62
	(86)	(62)		(85)		(85)	
Underwriting Costs (£)	2,149	2,011	-6.39	2,149	0.00	2,149	0.00
	(1,348)	(1,429)		(1,348)		(1,348)	
Prices:							
Interest Rates (bps)	399	317	-20.47	355	-11.08	435	+9.13
	(103)	(85)		(115)		(113)	
Origination Fees (£)	1,051	1,241	+18.12	1,288	+22.59	0	-100.00
	(665)	(831)		(806)		(0)	
Number of Products	220	242	+10.00	220	0.00	220	0.00
Quantities:							
Loan Amount (£)							
All	121,308	144,233	+18.90	146,394	+20.68	136,244	+12.31
	(85,968)	(114,224)		(106,282)		(90,295)	
First-time buyers	103,577	122,541	+18.31	126,321	+21.96	117,578	+13.52
	(58,826)	(72,336)		(77,077)		(65,128)	
Home movers	130,224	154,059	+18.30	156,486	+20.17	145,630	+11.83
	(95,546)	(127,583)		(116,979)		(99,280)	
Number of Mortgages							
All	16,617	20,622	+24.10	17,017	+2.41	16,584	-0.20
First-time buyers	7,159	8,941	+24.89	7,272	+1.57	7,142	-0.24
Home movers	9,458	11,681	+23.51	9,745	+3.03	9,442	-0.16

Notes—Columns (1) and (2) report outcomes for the estimated model in 2011Q3 and 2013Q3, respectively. Column (3) reports the percent change between column (2) and column (1). Column (4) reports outcomes of a counterfactual market based on 2011Q3, in which we reduce the costs of those lenders with positive FLS drawings by 40 bps. Column (5) reports the percent change between column (4) and column (1). Column (6) reports outcomes of a counterfactual market based on 2011Q3, in which we reduce the costs of lenders with positive FLS drawings by 40 bps and we do not allow lenders to charge origination fees. Column (7) reports the percent change between column (6) and column (1). Standard deviations in parentheses.

40 bps. We keep underwriting costs, the number of mortgage products, as well as borrower characteristics, constant at their 2011Q3 sample values. Lenders choose rates and fees according to the optimality conditions (11) and (14) based on their lower marginal costs because of their FLS take-up. We constrain fees to be non-negative and set them to zero if the right-hand side of equation (14) is negative evaluated at zero. We use iterated best responses that maximize lenders' profit functions to compute the equilibrium.

Column (4) of Table 7 reports market outcomes of this case. The top part confirms that FLS facilities reduced lenders' marginal costs, on average by 35 bps (because some lenders did not access FLS funds, the reduction in average marginal costs is lower than 40 bps). The middle part of the table shows that lenders more than pass this cost reduction

through to borrowers, because on average they decreased interest rates by 44 bps, implying a pass-through of $44/35 > 1$. Moreover, they increased origination fees by £237 even though underwriting costs did not change by construction. Hence, the model neatly captures the striking differential changes in interest rates and origination fees between 2011Q3 and 2013Q3 that we displayed in the left panel of Figure 4.

As a result of these changes, mortgage lending increases (as well as lender profits). The model predicts that borrowers' average loan size increases by approximately £25,000, or 21 percent of the 2011Q3 average loan amount, and the number of mortgages increases by 400, or 2.4 percent of 2011Q3 originations. Hence, the model implies a slightly larger change in the intensive margin (loan amount) and a smaller change in the extensive margin (number of mortgages) than those observed between 2011Q3 and 2013Q3. Two possible, complementary reasons for these differences are: (1) Perhaps the Bank of England Housing Survey data do not allow us to estimate the parameter ρ, which governs changes in the extensive margin, with sufficient precision and with heterogeneity across different borrower groups. (2) The new buyers who bought a house in 2013Q3 are marginal buyers, with smaller loans than those of inframarginal buyers; thus, because we underestimate the change in the extensive margin, we overestimate the change in the intensive margin.

Heterogeneity across Groups. Tables E5 and E6 in Appendix E report the effects of the FLS on all borrower groups in the first-time buyer and home mover segments, respectively, with two main findings. First, they confirm that different borrower groups tend to choose mortgage products with lower interest rates, even though they end up paying nontrivial fees. Moreover, the comparison between average prices paid in the pre-FLS market and the FLS market confirms that almost all borrower groups pay lower interest rates but higher fees in the FLS market. Second, all groups increase their loan sizes, with some households in areas with higher house prices, and thus higher loan sizes—such as London and Southern England—increasing their mortgage borrowing the most. According to standard welfare analysis based on revealed preferences, this increase in mortgage debt translates into an increase in consumer surplus, though the behavioral economics literature recommends caution in this interpretation of the increase in household borrowing (Heidhues and Kőszegi, 2010).

7.2 The Role of Fees

Our second counterfactual case focuses on the effects of two-part pricing with rates and fees by simulating a ban on origination fees. We believe that this is of interest for at

least two reasons. First, Greenwood and Scharfstein (2013) document the growth in fees associated with the expansion of household credit in an environment with declining interest rates, particularly the fees associated with residential mortgages. Section 3 documents this increase in our setting and Table 7 indicates that our model incorporates economic forces that can capture this increase. Second, the financial press reported that the Financial Conduct Authority (FCA) considered regulating mortgage origination fees.[22] Our estimated model seems well-suited to yield insights into how such regulation could affect market outcomes. In our context, studying a ban on fees allows us to understand whether two-part pricing strategies amplify the effects of central bank policies such as the FLS on aggregate lending.

Columns (6)–(7) of Table 7 report outcomes of a counterfactual market in which regulation does not allow lenders to charge origination fees. To understand the effects of such a ban on aggregate lending during the FLS program, we keep lenders' costs at the same level as in the market of columns (4)–(5), in which lenders have access to FLS funds.

Because of the constraint on fees, column (6) of Table 7 indicates that lenders increase the interest rates on their mortgage products by 80 bps compared to those of the unconstrained market of column (4). As a result of the changes in lender pricing, the average loan size declines by approximately £10,000, with minimal differences between first-time buyers and home movers. The number of mortgages originated declines by approximately 430 units.

Hence, these counterfactual results on banning fees have noteworthy implications for our research question of understanding the effects of central bank operations on market outcomes. Specifically, these results mean that the effects of a cost-reducing shock such as the FLS on aggregate mortgage lending would have been smaller if lenders' price discrimination strategies through menus of two-part tariffs were simultaneously banned. In turn, because aggregate borrowing decreases, they imply that banning fees would decrease consumer surplus under the traditional revealed preference approach (though the behavioral economics literature suggests that the welfare effects of such a ban may be more nuanced).

Heterogeneity across Groups. Tables E5 and E6 in Appendix E reveal some interesting effects of banning fees on borrower groups in the first-time buyer and home mover segments.

First, the increase in the interest rates paid is quite heterogeneous across groups of borrowers. On average, borrowers with larger mortgage loans suffer the largest rate hikes when fees are banned, because they chose products with lower rates and higher fees in the baseline economy in which lenders can charge fees, as Figure 3 documents.

[22] *Financial Times*, Mortgage lenders under FCA review for masking high fees, December 12, 2016.

Second, the ban on fees has heterogeneous effects on the borrowing of different groups: The average loan size decreases in most groups, though it increases in some groups. These heterogeneous effects arise for two main reasons. The traditional argument is that the ban on fees and thus on indirect price discrimination lead to higher borrowing costs (i.e., rates and fees combined) in some groups and lower borrowing costs in other groups. Hence, some groups decrease and others increase their loan amounts. In our setting, an additional effect kicks in: Different groups exhibit differential sensitivities to rates and fees, as we document in Section 6. Thus, they respond differently to the decrease in fees and the increase in rates due to the ban on fees. In general, borrowers with the largest loans in each geographic area (i.e., higher income and older borrowers) decrease their loan sizes by relatively more than other borrower groups, because, on average, they suffer the largest rate hikes and these rate changes impose a heavier burden on these borrowers with larger mortgage loans.

8 Conclusion

This paper studies the effects of central bank policies on credit markets by studying the UK residential mortgage market around the introduction of the Bank of England's Funding for Lending Scheme. We provide novel descriptive evidence on how UK lenders use menus of two-part tariffs consisting of origination fees and interest rates to segment the market, thereby price discriminating across heterogeneous households through quantity discounts. We further show how central bank policies affected lenders' pricing strategies by decreasing interest rates and increasing origination fees.

The descriptive analysis motivates us to develop and estimate an equilibrium model of the UK mortgage market with rich household heterogeneity. We use the estimated model to quantify the effects of the FLS on lenders' and borrowers' costs and mortgage lending. Our estimates indicate that the FLS program decreased participating lenders' costs by approximately 32–47 bps, which led them to decrease mortgage rates but to increase origination fees, consistent with our descriptive evidence. Overall, mortgage lending increased. Moreover, our counterfactual analysis shows that banning fees, thereby banning indirect price discrimination through two-part tariffs, would decrease aggregate mortgage lending.

We believe that the main contribution of our analysis is to emphasize how lenders' indirect price discrimination strategies affect the transmission of central bank policies to aggregate lending in markets with heterogeneous households.

References

Acharya, V. V., T. S. Oncu, M. Richardson, S. Van Nieuwerburgh, and L. J. White (2011): "The Government-Sponsored Enterprises," in *Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance*, ed. by V. Acharya, T. Cooley, M. Richardson, and I. Walter, pp. 429–42. Wiley Hoboken, NJ.

Adams, W., L. Einav, and J. Levin (2009): "Liquidity Constraints and Imperfect Information in Subprime Lending," *American Economic Review*, 99(1), 49–84.

Agarwal, S., G. Amromin, I. Ben-David, S. Chomsisengphet, T. Piskorski, and A. Seru (2017): "Policy Intervention in Debt Renegotiation: Evidence From the Home Affordable Modification Program," *Journal of Political Economy*, 125(3), 654–712.

Agarwal, S., I. Ben-David, and V. Yao (2017): "Systematic Mistakes in the Mortgage Market and Lack of Financial Sophistication," *Journal of Financial Economics*, 123(1), 42–58.

Agarwal, S., S. Chomsisengphet, N. Mahoney, and J. Stroebel (2017): "Do Banks Pass Through Credit Expansions to Consumers Who Want to Borrow?," *The Quarterly Journal of Economics*, 133(1), 129–190.

Agarwal, S., J. Grigsby, A. Hortaçsu, G. Matvos, A. Seru, and V. Yao (2024): "Searching for Approval," *Econometrica*, forthcoming.

Aguirregabiria, V., R. Clark, and H. Wang (2019): "The Geographic Flow of Bank Funding and Access to Credit: Branch Networks, Local Synergies, and Competition," Discussion Paper 13741, Centre for Economic Policy Research.

Alcaraz, C., S. Claessens, G. Cuadra, D. Marques-Ibanez, and H. Sapriza (2019): "Whatever it Takes. What's the Impact of a Major Nonconventional Monetary Policy Intervention?," Discussion Paper 2249, European Central Bank.

Allen, J., R. Clark, and J.-F. Houde (2019): "Search Frictions and Market Power in Negotiated Price Markets," *Journal of Political Economy*, 127(4), 1550–1598.

Andersen, S., J. Y. Campbell, K. M. Nielsen, and T. Ramadorai (2020): "Sources of Inaction in Household Finance: Evidence from the Danish Mortgage Market," *American Economic Review*, 110(10), 3184–3230.

Badarinza, C., J. Y. Campbell, and T. Ramadorai (2017): "What Calls to ARMs? International Evidence on Interest Rates and the Choice of Adjustable-rate Mortgages," *Management Science*, 64(5), 2275–2288.

Bank of England Prudential Regulation Authority and Financial Conduct Authority (2022): "Mortgage Lenders and Administrators Statistics," retrieved from https://www.bankofengland.co.uk/statistics/mortgage-lenders-and-administrators/2022/2022-q3 on December 23rd, 2022.

Belgibayeva, A., T. Bono, P. Bracke, J. Cocco, and T. Majer (2020): "When Discounted Rates End: The Cost of a Taking Action in the Mortgage Market," Occasional Paper 54, Financial Conduct Authority.

Benetton, M. (2021): "Leverage Regulation and Market Structure: An Empirical Model of the UK Mortgage Market," *Journal of Finance*, 76(6), 2997–3053.

Benetton, M., P. Eckley, N. Garbarino, L. Kirwin, and G. Latsi (2021): "Capital requirements and mortgage pricing: Evidence from Basel II," *Journal of Financial Intermediation*, 48, 100883.

Benetton, M., and D. Fantino (2021): "Targeted Monetary Policy and Bank Lending Behavior," *Journal of Financial Economics*, 142(1), 404–429.

Best, M. C., J. Cloyne, E. Ilzetzki, and H. Kleven (2020): "Estimating the Elasticity of Intertemporal Substitution Using Mortgage Notches," *Review of Economic Studies*, 87(2), 656–690.

Borio, C., and A. Zabai (2016): "Unconventional Monetary Policies: a Re-appraisal," Discussion paper, Bank of International Settlement.

Brueckner, J. K. (1994): "Borrower Mobility, Adverse Selection, and Mortgage Points," *Journal of Financial Intermediation*, 3(4), 416–441.

Buchak, G., G. Matvos, T. Piskorski, and A. Seru (2018): "Fintech, Regulatory Arbitrage, and the Rise of Shadow Banks," *Journal of Financial Economics*, 130(3), 453–483.

——— (2024): "Beyond the Balance Sheet Model of Banking: Implications for Bank Regulation and Monetary Policy," *Journal of Political Economy*, forthcoming.

Churm, R., M. Joyce, G. Kapetanios, and K. Theodoridis (2021): "Unconventional Monetary Policies and the Macroeconomy: The Impact of the UK's QE2 and Funding for Lending Scheme," *The Quarterly Review of Economics and Finance*, 80, 721–736.

Churm, R., A. Radia, J. Leake, S. Srinivasan, and R. Whisker (2012): "The Funding for Lending Scheme," *Bank of England Quarterly Bullettin*, Q4, 306–320.

Cloyne, J., K. Huber, E. Ilzetzki, and H. Kleven (2019): "The Effect of House Prices on Household Borrowing: A New Approach," *American Economic Review*, 109(6), 2104–2136.

Crawford, G. S., N. Pavanini, and F. Schivardi (2018): "Asymmetric Information and Imperfect Competition in Lending Markets," *American Economic Review*, 108(7), 1659–1701.

Crawford, G. S., O. Shcherbakov, and M. Shum (2019): "Quality Overprovision in Cable Television Markets," *American Economic Review*, 109(3), 956–995.

Cuesta, J. I., and A. Sepúlveda (2021): "Price Regulation in Credit Markets: A Trade-off between Consumer Protection and Credit Access," Mimeo, Stanford University.

Di Maggio, M., A. Kermani, B. J. Keys, T. Piskorski, R. Ramcharan, A. Seru, and V. Yao (2017): "Interest Rate Pass-Through: Mortgage Rates, Household Consumption, and Voluntary Deleveraging," *American Economic Review*, 107(11), 3550–88.

Di Maggio, M., A. Kermani, and C. Palmer (2020): "How Quantitative Easing Works: Evidence on the Refinancing Channel," *Review of Economic Studies*, 87(3), 1498–1528.

Diamond, D. W., and R. G. Rajan (2000): "A Theory of Bank Capital," *The Journal of Finance*, 55(6), 2431–2465.

Economides, N., K. Seim, and V. B. Viard (2008): "Quantifying the Benefits of Entry into Local Phone Service," *The RAND Journal of Economics*, 39(3), 699–730.

Egan, M., A. Hortaçsu, and G. Matvos (2017): "Deposit Competition and Financial Fragility: Evidence from the US Banking Sector," *American Economic Review*, 107(1), 169–216.

Einav, L., A. Finkelstein, and N. Mahoney (2021): "The IO of Selection Markets," in *Handbook of Industrial Organization*, ed. by K. Ho, A. Hortaçsu, and A. Lizzeri, vol. 5, pp. 389–426. Elsevier.

Einav, L., M. Jenkins, and J. Levin (2012): "Contract Pricing in Consumer Credit Markets," *Econometrica*, 80(4), 1387–1432.

Finkelstein, A., and J. Poterba (2014): "Testing for Asymmetric Information Using "Unused Observables" in Insurance Markets: Evidence From the U.K. Annuity Market," *The Journal of Risk and Insurance*, 81(4), 709–734.

Fisher, J., A. Gavazza, L. Liu, T. Ramadorai, and J. Tripathy (2024): "Refinancing Cross-Subsidies in the UK Mortgage Market," *Journal of Financial Economics*, forthcoming.

Fuster, A., M. Plosser, P. Schnabl, and J. Vickery (2019): "The Role of Technology in Mortgage Lending," *The Review of Financial Studies*, 32(5), 1854–1899.

Ghent, A. C., and M. Kudlyak (2011): "Recourse and Residential Mortgage Default: Evidence from US States," *The Review of Financial Studies*, 24(9), 3139–3186.

Greenwald, D. L. (2018): "The Mortgage Credit Channel of Macroeconomic Transmission," Mimeo, Massachusetts Institute of Technology.

Greenwood, R., and D. Scharfstein (2013): "The Growth of Finance," *Journal of Economic Perspectives*, 27(2), 3–28.

Grubb, M. D., and M. Osborne (2015): "Cellular Service Demand: Biased Beliefs, Learning, and Bill Shock," *American Economic Review*, 105(1), 234–271.

Grunewald, A., J. A. Lanning, D. C. Low, and T. Salz (2020): "Auto Dealer Loan Intermediation: Consumer Behavior and Competitive Effects," Working Paper 28136, National Bureau of Economic Research.

Guiso, L., A. Pozzi, A. Tsoy, L. Gambacorta, and P. E. Mistrulli (2022): "The cost of steering in financial markets: Evidence from the mortgage market," *Journal of Financial Economics*, 143(3), 1209–1226.

Gurun, U. G., G. Matvos, and A. Seru (2016): "Advertising Expensive Mortgages," *The Journal of Finance*, 71(5), 2371–2416.

Hastings, J., A. Hortaçsu, and C. Syverson (2017): "Sales Force and Competition in Financial Product Markets: The Case of Mexico's Social Security Privatization," *Econometrica*, 85(6), 1723–1761.

Heidhues, P., and B. Kőszegi (2010): "Exploiting Naïvete about Self-Control in the Credit Market," *American Economic Review*, 100(5), 2279–2303.

Imbens, G., and J. Angrist (1994): "Estimation and Identification of Local Average Treatment Effects," *Econometrica*, 62, 467–475.

Lea, M. (2010): "International Comparison of Mortgage Product Offerings," Discussion paper, Research Institute for Housing America.

Lemmon, M. L., M. R. Roberts, and J. F. Zender (2008): "Back to the Beginning: Persistence and the Cross-Section of Corporate Capital Structure," *The Journal of Finance*, 63(4), 1575–1608.

Leslie, P. (2004): "Price Discrimination in Broadway Theater," *The RAND Journal of Economics*, 35(3), 520–541.

Liebman, J. B., and R. J. Zeckhauser (2004): "Schmeduling," Mimeo, Harvard University.

Liu, L. (2019): "Non-Salient Fees in the Mortgage Market," Mimeo, Imperial College London.

Luo, Y., I. Perrigne, and Q. Vuong (2018): "Structural Analysis of Nonlinear Pricing," *Journal of Political Economy*, 126(6), 2523–2568.

Matcham, W. (2023): "Risk-Based Borrowing Limits in Credit Card Markets," Mimeo, London School of Economics.

McManus, B. (2007): "Nonlinear pricing in an oligopoly market: The case of specialty coffee," *The RAND Journal of Economics*, 38(2), 512–532.

Miles, D. (2004): "The UK Mortgage Market: Taking a Longer-Term View," Discussion paper, Imperial College London.

Miravete, E. J. (2002): "Estimating Demand for Local Telephone Service with Asymmetric Information and Optional Calling Plans," *The Review of Economic Studies*, 69(4), 943–971.

Nelson, S. (2023): "Private Information and Price Regulation in the US Credit Card Market," Mimeo, University of Chicago.

Office for National Statistics (2015): "UK House Price Index," Statistical Bulletins.

Oren, S. S. (2012): "Nonlinear Pricing," in *The Oxford Handbook of Pricing Management*, ed. by Ö. Özer, and R. Phillips, pp. 492–521. Oxford University Press.

Robles-Garcia, C. (2022): "Competition and Incentives in Mortgage Markets: The Role of Brokers," Mimeo, Stanford University.

Rotemberg, J. (2011): "Fair Pricing," *Journal of the European Economic Association*, 9(5), 952–981.

Scharfstein, D., and A. Sunderam (2016): "Market Power in Mortgage Lending and the Transmission of Monetary Policy," Mimeo.

Stanton, R., and N. Wallace (1998): "Mortgage choice: What's the point?," *Real Estate Economics*, 26(2), 173–205.

Stein, J. C. (1995): "Prices and Trading Volume in the Housing Market: A Model with Down-Payment Effects," *The Quarterly Journal of Economics*, 110(2), 379–406.

Train, K. E. (1986): *Qualitative Choice Analysis: Theory, Econometrics, and an Application to Automobile Demand*, vol. 10. MIT press.

Van Dijk, R., and S. Garga (2006): "UK Mortgage Underwriting," Technical report, Oxera Consulting.

Varian, H. (1989): "Price Discrimination," in *Handbook of Industrial Organization*, ed. by R. Schmalensee, and R. Willig, vol. I, pp. 597–654. Elsevier.

Verboven, F. (2002): "Quality-Based Price Discrimination and Tax Incidence: Evidence from Gasoline and Diesel Cars," *The RAND Journal of Economics*, 33(2), 275–297.

Wilson, R. B. (1993): *Nonlinear Pricing*. Oxford University Press.

Woodward, S. E., and R. E. Hall (2012): "Diagnosing Consumer Confusion and Sub-Optimal Shopping Effort: Theory and Mortgage-Market Evidence," *American Economic Review*, 102(7), 3249–3276.

Xiao, K. (2020): "Monetary Transmission through Shadow Banks," *Review of Financial Studies*, 33(6), 2379–2420.

APPENDICES

The appendices are structured as follows. Appendix A explains our procedure for constructing the estimation dataset. Appendix B provides institutional background on the Funding for Lending Scheme program. Appendix C reports additional descriptive analyses. Appendix D details the formulas of the demand elasticities and consumer surplus. Appendix E reports additional estimation results.

A Dataset Construction

In this Appendix, we describe our procedure for constructing the dataset used in the estimation, which requires merging the PSD and the Moneyfacts dataset.

First, we construct a product-type definition based on variables that are common to both Moneyfacts and the PSD. The product-type definition is based on the following characteristics: interest-rate type (fixed or variable); length of the fixation period (e.g., 2 years, 5 years); LTV band (e.g., 70-75, 75-80); and lender identifier in the PSD. Moneyfacts reports more detailed information on the brand associated with the mortgage product, but the PSD only reports the more aggregated banking entity, which is the one we use for matching purposes. For example, HSBC and First Direct are both retail divisions of HSBC Bank Plc, and their mortgages are reported as being issued by HSBC in the PSD.

Second, for each product type, quarter, interest rate, and origination fee, we drop all repeated observations in Moneyfacts. Given our product-type definition, the quarterly interval, and the rate-fee pair, we can obtain multiple observations because of: (1) different brands under the same lender; and (2) different observations across months within the same quarter. We keep the product with the highest fee if we observe multiple fees for a given product type, quarter, and interest rate (this can happen if the lender changes the fee in a month within the quarter without changing the interest rate). This second step provides us with a product list for each quarter in Moneyfacts we can merge with PSD using product type, quarter, and interest rate as matching variables (we remind the readers that the PSD does not report origination fees).

Third, we impute missing product characteristics in the PSD other than the fee. We identify three categories of observations: (1) those with no missing characteristics (30 percent of all PSD observations); (2) those with missing initial fixation period only (30 percent); and (3) those with more than one missing variable (40 percent). These categories are often associated with specific lenders, because the reporting of some variables was optional before

2015 and thus some lenders (almost) always reported them, while others (almost) never did. For observations in category (2), we impute the length of the initial fixation period by recovering it from Moneyfacts based on the lender, interest-rate type, LTV band, and the interest rate. For category (3) we impute all missing variables using the predicted values from regression models based on the mortgage characteristics and borrowers demographics of mortgages with no missing values. This procedure allows us to retain more than 90 percent of the observations in the PSD.

Fourth, based on our definition of a product type—a combination of three non-price characteristics: (1) lender; (2) interest-rate type with fixation period; and (3) maximum LTV ratio—and its interest rate observed in the PSD, we recover the corresponding origination fee from the Moneyfacts dataset.

Finally, the resulting dataset still features many product types with minimal market shares. We combine all products with a market share below 0.1 percent into a representative "outside" product, whose characteristics equal the (weighted) average characteristics of the underlying mortgages. As a result, our final dataset contains 245 product types (124 for first-time buyers, 121 for home movers) and 374 products (186 for first-time buyers, 188 for home movers).

B The Funding For Lending Scheme

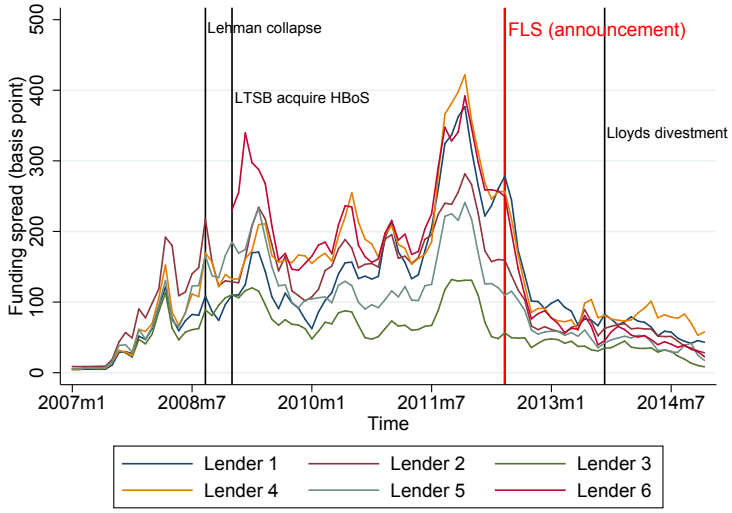
On June 14, 2012, the Governor of the Bank of England, Mervyn King, announced the introduction of the Bank of England and HM Treasury FLS program, which officially started on July 13, 2012. The scheme was part of the larger monetary stimulus package that the Bank of England had pursued since the onset of the financial crisis, along the lines of similar programs of other central banks (Borio and Zabai, 2016).[23]

The timing of the FLS followed an intensification of the European Sovereign Debt Crisis and an increase in banks' funding costs for major UK lenders, which in turn led to an increase in loan rates. Figure B1 displays funding spreads for the six (anonymized) largest UK lenders.[24] Black vertical lines denote key banking events, and the red vertical line marks the announcement of the FLS. The time series of these funding costs display two large

[23]The Bank of England cut the 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 UK government securities, but also smaller quantities of high-quality corporate bonds.

[24]More formally, Figure B1 reports the constant maturity secondary market spreads to mid-swaps for the largest UK lenders' 5-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 B1: Funding Costs



Notes—This figure displays the funding spreads of the six largest UK lenders.

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 program provides direct funding to banks and building societies for an extended period at lower rates than those prevailing on the market, with the stated goal of promoting lending to households and firms. The scheme's incentives operate through both quantities and prices. As for quantities, the amount of funding available varies with the amount banks lend out, as follows. First, each lender can borrow from the Bank of England up to 5 percent of its existing stock of loans to households and to firms in June 2012. Second, banks can borrow beyond this 5 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, with no constraint on the additional amount they can borrow for this purpose. As for the scheme's incentive for prices, the cost depends on the amount banks lend out. Banks that maintain or expand lending pay an annual fee of 25 bps for the amount they borrow from FLS facilities. Banks that reduce net lending pay an additional fee of 25 bps for each percentage point of decline in net lending. This fee increases linearly up to a maximum of 150 bps for banks that reduce net lending by more than 5 percent.

By the end of 2014, the FLS had recorded 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. Churm, Radia, Leake, Srinivasan, and Whisker (2012) provide a more detailed description of the FLS, as well as some evidence on the short-term effects of the scheme on the interest rates lenders charged to firms and households. The FLS closed at the end of Feb 2018.

C Data: Additional Descriptive Analyses

The goal of this Appendix is to provide additional descriptive patterns in our data.

C.1 More Facts about Mortgage Pricing

We now provide additional details on mortgage pricing using the Moneyfacts data.

Rate Decomposition. Table C1 presents the coefficient estimates of several regressions that aim to decompose the variation in interest rates across mortgage products. The dependent variable is the interest rate r_{jkt} of product j, product type k in month t. We gradually enrich the product attributes included among the explanatory variables. The specification of column (1) includes time fixed effects only, and the R^2 indicates that they account for 20.7 percent of the sample rate variation. Specification (2) further includes indicator variables for the maximum LTV of the mortgage product. The R^2 increases substantially—from 20.7 percent in column (1) to 63.5 percent in column (2)—thereby indicating that the variation across LTV bands is the major cross-sectional driver of UK mortgage rates.

Specification (3) further includes fixed effects for the combination of interest rate type (e.g., fixed vs. variable) and the duration of the deal (e.g., 2 vs. 3 years).[25] Lenders price these mortgage products differently because the resulting loans carry different interest-rate risks. The R^2 of the regression increases to 73.4 percent.

Specification (4) further includes lender fixed effects, which increase the R^2 to 78.1 percent. Specification (5) further includes fees. The R^2 reaches 79.2 percent.

[25]Some lenders offer mortgage products with variable rates with a spread over a benchmark rate lower for, say, the first two years, and higher thereafter. Hence, these mortgage products are 2-year variable rates.

Table C1: Interest Rate Decomposition

	(1)	(2)	(3)	(4)	(5)
$60 < \text{LTV} \leq 70$		-0.057***	-0.076***	0.159***	0.163***
		(0.008)	(0.007)	(0.007)	(0.007)
$70 < \text{LTV} \leq 75$		0.279***	0.248***	0.384***	0.359***
		(0.007)	(0.006)	(0.006)	(0.006)
$75 < \text{LTV} \leq 80$		0.734***	0.713***	0.821***	0.807***
		(0.008)	(0.007)	(0.007)	(0.006)
$80 < \text{LTV} \leq 85$		1.197***	1.117***	1.283***	1.259***
		(0.008)	(0.007)	(0.006)	(0.006)
$85 < \text{LTV} \leq 90$		1.969***	1.827***	2.016***	1.991***
		(0.008)	(0.007)	(0.007)	(0.006)
$90 < \text{LTV} \leq 95$		2.349***	2.158***	2.250***	2.167***
		(0.014)	(0.012)	(0.011)	(0.011)
Home movers			0.006*	0.002	0.010***
			(0.004)	(0.003)	(0.003)
Fix 3 years			0.297***	0.327***	0.322***
			(0.005)	(0.005)	(0.005)
Fix 5 years			0.701***	0.759***	0.748***
			(0.005)	(0.004)	(0.004)
Discounted			-0.020**	0.126***	0.124***
			(0.008)	(0.008)	(0.007)
Discounted 2 years			-0.296***	-0.314***	-0.302***
			(0.005)	(0.005)	(0.005)
Fees (£1,000)					-0.229***
					(0.003)
Time f.e.	Yes	Yes	Yes	Yes	Yes
Lender f.e.	No	No	No	Yes	Yes
R^2	0.207	0.635	0.734	0.781	0.792
Observations	101,185	101,185	101,185	101,185	101,185

Notes—This table presents the coefficient estimates of several regressions in which the dependent variable is the interest rate r_{jkt} of product j, product type k in month t.

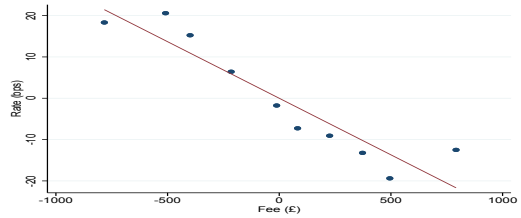
Rate-fee Correlation. We now provide additional details on the relationship between rates and fees in the Moneyfacts data. To this goal, we estimate the following regressions:

$$r_{jkt} = \chi^r_{kt} + \upsilon^r_{jkt}, \tag{C1}$$

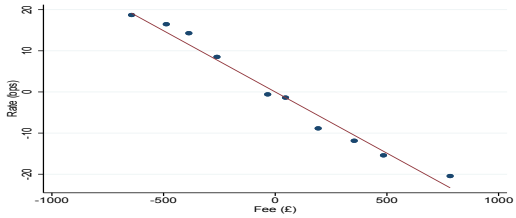
$$f_{jkt} = \chi^f_{kt} + \upsilon^f_{jkt}, \tag{C2}$$

where r_{jkt} and f_{jkt} are the interest rate and the fee, respectively, of product j, product type k, in month t; χ^r_{kt} and χ^f_{kt} are product type-month fixed effects; and υ^r_{jkt} and υ^f_{jkt} are unobservables. The inclusion of product type-month fixed effects implies that we exploit exclusively mortgage products with multiple rate-fee combinations, as in the regressions of columns (2)–(7) of Table 2.

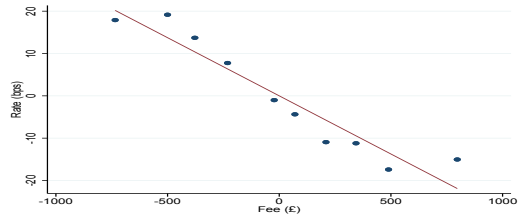
Figure C1: Correlation between Residual Rates and Fees Across Products



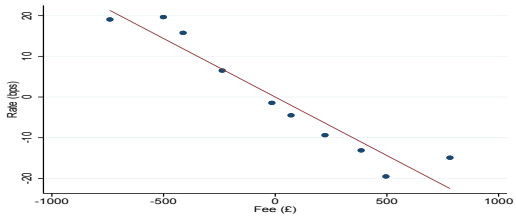
(a) LTV $\leq$ 80



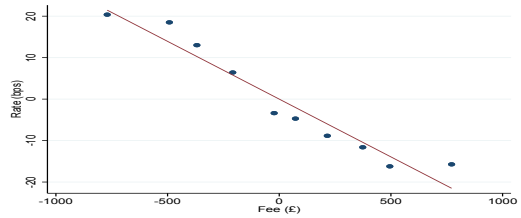
(b) LTV $>$ 80



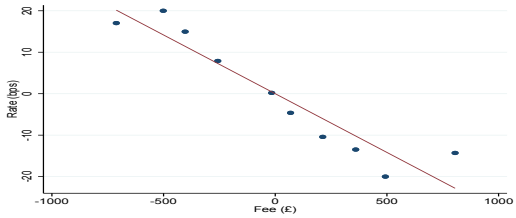
(c) First-time Buyers



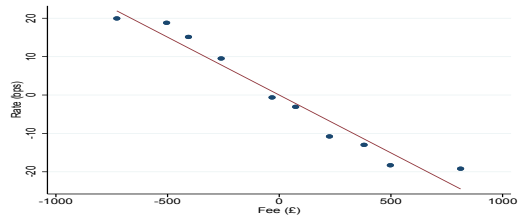
(d) Home Movers



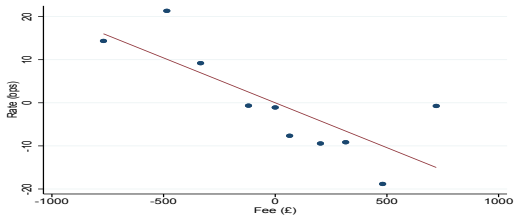
(e) Big 6



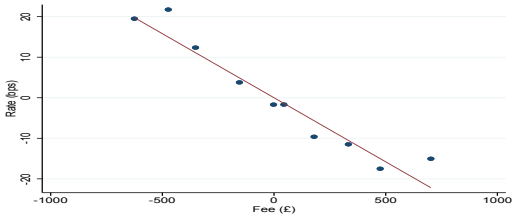
(f) Small Lenders



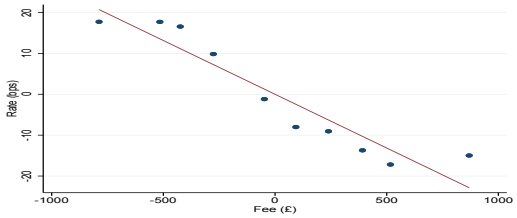
(g) Fixed Rate



(h) Variable Rate



(i) Pre-FLS



(j) Post-FLS

Notes—The Figure reports the binned scatterplots of the estimated residuals ($\hat{v}^r_{jkt}, \hat{v}^f_{jkt}$) of equations (C1) and (C2) for several groups of mortgage products: products with a maximum LTV equal or below 80 percent (top-left); products with a maximum LTV above 80 percent (top-right); product offered to first-time buyers (second row-left) and home movers (second row-right); products offered by the largest 6 lenders (third row-left); products offered by smaller lenders (third row-right); products offered with a fixed interest rate (fourth row-left); products offered with a variable interest rate (fourth row-right); products offered before the FLS, until July 2012 (bottom-left); and products offered after the FLS, from August 2012 (bottom-right).

Figure C1 displays several binned scatterplots of the estimated residuals of equation (C1) on the vertical axis and of equation (C2) on the horizontal axis for several groups of mortgage products: products with a maximum LTV equal or below 80 percent (top-left); products with a maximum LTV above 80 percent (top-right); product offered to first-time buyers (second row-left) and home movers (second row-right); products offered by the largest 6 lenders (third row-left); products offered by smaller lenders (third row-right); products offered with a fixed interest rate (fourth row-left); products offered with a variable interest rate (fourth row-right); products offered before the FLS, until July 2012 (bottom-left); and products offered after the FLS, from August 2012 (bottom-right).

All these plots show a negative relation between residual fees and residual rates. The magnitudes are also quite similar across plots: On average, a £1,000-higher fee is associated with an approximately 25-bps-lower interest rate.

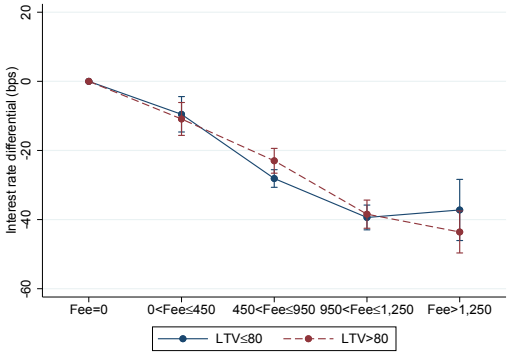
We further explore the rate-fee schedule by estimating the following flexible specification:

$$r_{jkt} = \sum_{b} \eta_b \mathbb{1}\{fee_{jkt} \in b\} + \chi_{kt} + \upsilon_{jkt}, \tag{C3}$$

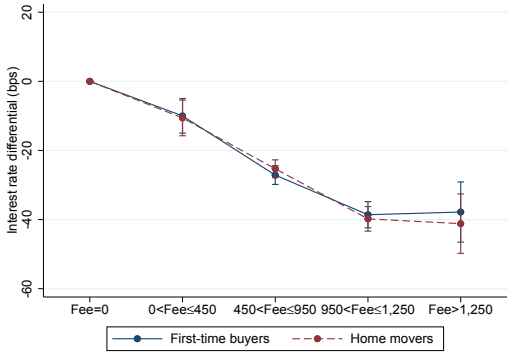
where $\mathbb{1}\{fee_{jkt} \in b\}$ are indicator variables equal to one if the fees of product j, product type k, in month t belong to the following bands: (1) fees between £1 and £450; (2) fees between £451 and £950; and (3) fees between £951 and £1,250. Products with zero fees are the excluded category. χ_{kt} are product type-month fixed effects, and υ_{jkt} are unobservables.

Figure C2 displays the estimated η_b of equation (C3) for different groups of products. Relative to zero-fee mortgages, on average mortgages with fees between £1 and £450 feature 10-basis-point-lower interest rates for products with LTV equal or below 80 percent, offered by the largest six lenders, in both market segments (first-time buyers and home movers), and with either a fixed or an adjustable rate. The point estimate of the decrease in rates is slightly lower for mortgage products offered by smaller lenders, but the magnitudes are not statistically different. The increase in the fees from £1–450 to £451–950 is associated with an average decrease in interest rates by 15–20 bps, corresponding to a 25–30 bps discount relative to a zero-fee mortgage. Increasing the fees from £451–950 to £951–1,250 yields a similar rate decrease by 15–20bps. Finally, increasing fees further above £1,250 does not seem to lead to additional reductions in interest rates, although there are only a few products with fees greater than £1,250 and thus the estimates are not precise.

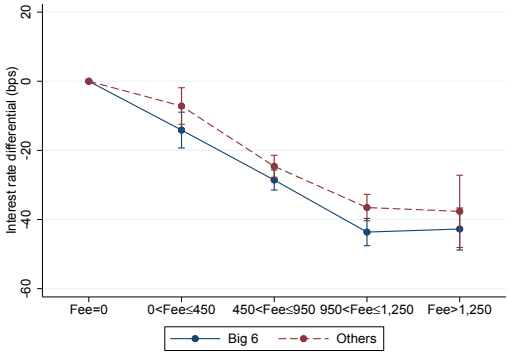
Figure C2: Rate-Fee Schedules Across Products



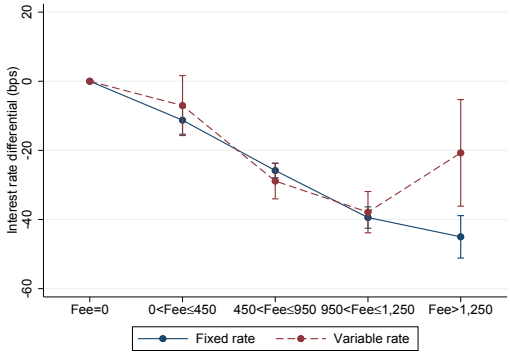
(a) LTV



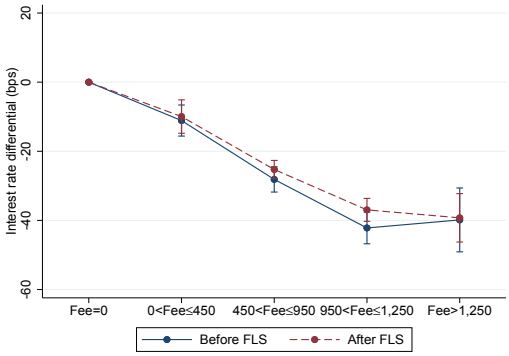
(b) Borrower Type



(c) Lenders



(d) Rate Type



(e) Pre/Post FLS

Notes—The Figure reports the estimated η_b of equation (C3) for several different groups of products.

Table C2: Number of Quotes and Loan Amounts within LTV Bands

	Number of quotes				Loan amount			
	FTB		HM		FTB		HM	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LTV $\leq$ 70	2.78	2.33	2.80	2.34	133.92	91.99	141.45	111.40
70 $<$ LTV $\leq$ 75	3.29	2.78	3.29	2.72	130.84	69.63	178.24	113.01
75 $<$ LTV $\leq$ 80	2.41	1.58	2.40	1.61	146.74	89.41	180.99	115.61
80 $<$ LTV $\leq$ 85	2.99	3.10	2.84	2.62	136.26	82.34	184.90	103.57
85 $<$ LTV $\leq$ 90	2.89	3.09	2.57	2.63	129.88	62.67	165.40	78.49
90 $<$ LTV $\leq$ 95	2.17	2.77	2.21	2.69	134.44	47.21		

Notes—Summary statistics for the number of quotes in Moneyfacts and loan amounts (in £,000) in PSD 001 within LTV bands in each market segment. The number of mortgage loans in PSD 001 with LTVs above 90 in the home mover segment does not satisfy the restrictions described in Appendix A and thus the cells are empty.

Two-part pricing and default risk. We now report additional details on some empirical patterns mentioned in Section 3 that suggest that lenders do not construct menus of two-part tariffs to screen borrowers for their default risk.

Specifically, if lenders construct menus composed of different rate-fee quotes to screen borrowers ex-ante based on their default risk, we might expect the number of quotes to be higher at higher LTV bands, that is the segment of the market with higher default rates. Table C2 reports the number of products by type/month for different LTV bands in each market segment. The number of products by type/month does not display a clear pattern across LTV bands. Critically, we do not observe a larger number of rate-fee quotes and thus finer screening through two-part pricing at higher LTV products—probably, the opposite.

Moreover, we investigate whether lenders screen borrowers at high LTVs using a different rate-fee trade-off than at low LTVs. For example, riskier borrowers may be more likely to choose zero-fee products than safer borrowers. This is because, in anticipation of their future default, risky borrowers should be less willing to pay upfront fees to reduce their future interest payments than safer borrowers. Because lenders' incentives to screen borrowers are higher on high-LTV (riskier) mortgages than at low-LTV (safer) mortgages, lenders should charge a larger interest rate differential between zero-fee products and positive-fee products on high-LTV mortgages than on low-LTV mortgages.

The comparison between panels (a) and (b) of Figure C1 above does not seem to show evidence for such a differential rate-fee relationship between riskier, high-LTV and safer, low-

Table C3: Rate-Fee Relationship across LTV Bands

	(1)	(2)
Fees (£1,000)	-0.222***	
	(0.024)	
No Fee		0.308***
		(0.028)
Interacted with:		
$70 < \text{LTV} \leq 75$	-0.118***	0.051
	(0.030)	(0.032)
$75 < \text{LTV} \leq 80$	-0.047	0.062**
	(0.037)	(0.031)
$80 < \text{LTV} \leq 85$	-0.079**	0.071**
	(0.031)	(0.033)
$85 < \text{LTV} \leq 90$	-0.056*	-0.029
	(0.030)	(0.035)
$90 < \text{LTV} \leq 95$	-0.149**	-0.045
	(0.066)	(0.061)
Product-Time	Yes	Yes
R^2	0.936	0.931
Observations	90,305	90,305

Notes—Column (1) reports the estimates of equation (C4) using fees as a continuous explanatory variable. Column (2) reports the estimates of equation (C4) using an indicator variable equal to one if fees are zero, and zero otherwise, as the explanatory variable. Standard errors clustered at the product and time level in parenthesis.

LTV mortgages. In addition, we investigate more formally the rate-fee relationship across LTVs by estimating the following regression:

$$r_{jkt} = \sum_{d} \eta_d f_{jkt} \mathbb{1}\{LTV_{jkt} \in d\} + \chi_{kt} + \upsilon_{jkt}, \tag{C4}$$

where r_{jkt} is the interest rate of product j, product type k, in month t; f_{jkt} is the corresponding fee; $\mathbb{1}\{LTV_{jkt} \in d\}$ are indicator variables equal to one if the maximum LTV of product j, product type k, in month t equals: 75, 80, 85, 90, and 95, respectively; χ_{kt} are product type-month fixed effects and υ_{jkt} are unobservables. The coefficients of interest are the η_d, which measure the rate of substitution between initial interest rates and origination fees within a product type-time pair across different LTV bands. Following the estimation of equation (1), we estimate two specifications: the first one with fees in level as a continuous variable; the second with an indicator variable equal to one for products with no fees, and zero otherwise.

Table C3 reports the coefficient estimates. The first column reports that a £1,000-higher origination fee corresponds to a 22-bps-lower interest rate within the same product type-month pair. Critically, we do not find any monotonic pattern in the rate-fee relationship

Table C4: No-Fee Product Choice

	(1)	(2)	(3)	(4)	(5)	(6) FTB	(7) HM
Age	0.061	0.049	0.033	-0.027	-0.004	0.051*	-0.019
	(0.135)	(0.134)	(0.137)	(0.076)	(0.019)	(0.028)	(0.017)
Income	-0.004	0.011	0.012	0.001	-0.001	-0.015	0.001
	(0.009)	(0.014)	(0.014)	(0.003)	(0.001)	(0.009)	(0.001)
Loan amount (log)		-0.042***	-0.047***	-0.051***	-0.038***	-0.044***	-0.034***
		(0.014)	(0.014)	(0.009)	(0.006)	(0.014)	(0.007)
Time f.e.	No	No	Yes	Yes	Yes	Yes	Yes
Lender f.e.	No	No	No	Yes	No	No	No
Product f.e.	No	No	No	No	Yes	Yes	Yes
R^2	0.000	0.005	0.019	0.211	0.391	0.343	0.446
Observations	193,860	193,860	193,860	193,860	193,860	85,346	108,514

Notes—This table reports the coefficient estimates of linear probability model regressions in which the outcome variable equals one if the household chooses a no-fee product, and zero otherwise.

across LTV bans. Similarly, the estimates in the second column show that lenders offer products with zero fees at an interest rate that is on average 31 bps higher than a product with identical non-price characteristics but with a positive fee. Again, although the magnitude of the pricing schedule varies somewhat across LTV bands, we do not find any clear monotonic pattern.

No-Fee Product Choice. To further understand borrowers' choices of no-fee products, Table C4 reports the coefficient estimates of several linear probability model regressions in which the outcome variable equals one if the household chooses a no-fee mortgage product, and zero otherwise.

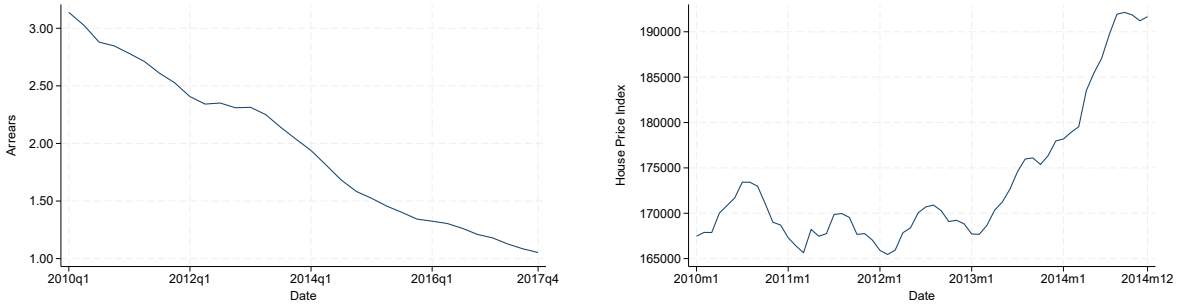
These regressions confirm that the loan size is negatively correlated with the choice of a no-fee product. Interestingly, this choice is uncorrelated with the demographic characteristics available, such as age and income, once we control for loan size.

C.2 Additional Market Trends

House Prices and Mortgage Arrears. The left panel of Figure C3 displays the UK House Price Monthly Index calculated by the Office of National Statistics for the period 2010–2014 (Office for National Statistics, 2015). It shows that house prices were broadly flat in 2010–2012, and started to increase rapidly from 2013.

The right panel of Figure C3 displays the time series of mortgage arrears as a share of total loan balances, from subtable 11 of Bank of England Prudential Regulation Authority

Figure C3: House Prices and Mortgage Arrears



Notes—Left panel: UK House Price Monthly Index calculated by Office for National Statistics (2015). Right panel: Quarterly balances of mortgages in arrears as a share of total loan balances, from subtable 11 of Bank of England Prudential Regulation Authority and Financial Conduct Authority (2022).

and Financial Conduct Authority (2022). Our PSD origination data cover 2010–2014, but we display mortgage arrears until 2017, because most arrears occur in the first few years after originations. The right panel shows that the level of mortgage arrears was low and declined during 2010–2017. Because mortgage arrears are a stock variable, the declining series suggest that new flows—and thus, recent mortgages—have fewer arrears than the stock of older mortgages.

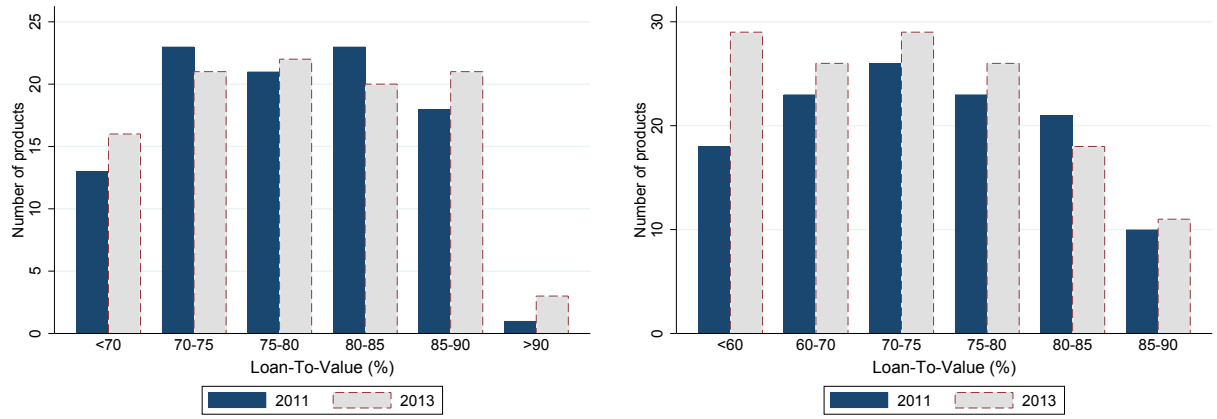
Mortgage Products. Figure C4 documents the number of product offerings in 2011Q3 and in 2013Q3 by LTV band in the first-time buyer (left panel) and home mover (right panel) segments. Lenders expanded their offerings of high-LTV products in the first-time buyer segment, thereby allowing borrowers to obtain larger mortgages amid rising house prices. This expansion of high-LTV products is smaller in the home mover segment, presumably because home movers are simultaneously buyers and sellers in the housing market, and thus their LTVs are less affected by the increase in house prices than those of first-time buyers. Nevertheless, trading volume is correlated with house prices (Stein, 1995), and thus lenders may want to expand their product offerings when turnover in the housing market is high.

D Model: Additional Results

In this Appendix, we provide the formulas of the demand elasticities.

The derivatives of the individual loan demand with respect to the interest rate and the

Figure C4: Product Offerings



Notes—The figure displays the number of product offerings in 2011Q3 and in 2013Q3 by LTV band in the first-time buyer (left panel) and home mover (right panel) segments.

fee, respectively, equal

$$\frac{\partial q_{ijmt}}{\partial r_{jt}} = -(1+\alpha_m)\frac{q_{ijmt}}{r_{jt}}, \tag{D1}$$

$$\frac{\partial q_{ijmt}}{\partial f_{jt}} = -\frac{\psi_m}{Y_i - f_{jt}} q_{ijmt}. \tag{D2}$$

The derivatives of the product demand equal

$$\frac{\partial s_{ijmt}}{\partial r_{jt}} = -\alpha_m \exp\left(\delta_{jmt}+\zeta_i\right)\left(\frac{1-s_{ijmt|j\in J_i}}{\rho_m} + s_{ijmt|j\in J_i} s_{i0mt}\right)\frac{s_{ijmt}}{r_{jt}}, \tag{D3}$$

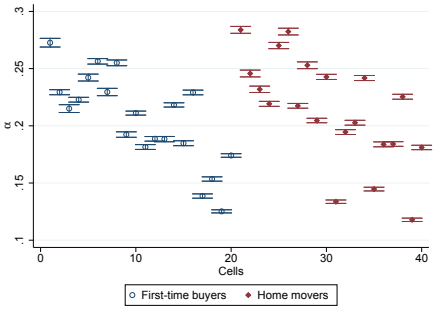
$$\frac{\partial s_{ijmt}}{\partial f_{jt}} = -\frac{\gamma_m}{(Y_i - f_{jt})^{\psi_m}}\left(\frac{1-s_{ijmt|j\in J_i}}{\rho_m} + s_{ijmt|j\in J_i} s_{i0mt}\right) s_{ijmt}. \tag{D4}$$

Individual elasticities follow from equations (D1)–(D4). We then compute the elasticities at the product-market-quarter level by averaging across households in each market m and quarter t.

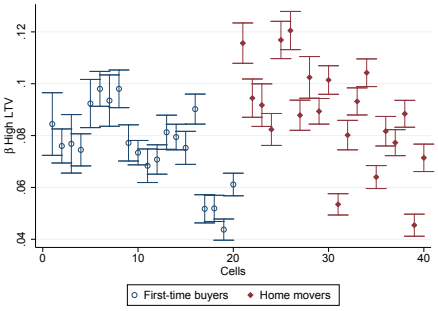
E Estimation: Additional Results

Demand Parameters. Figure E1 presents the point estimates and 95 percent confidence intervals of the demand parameters of each group. Groups are ordered as in Tables E5 and E6, e.g., group 1 comprises young, low-income, first-time buyers in the London region. We display first-time buyer groups in blue and home mover groups in red.

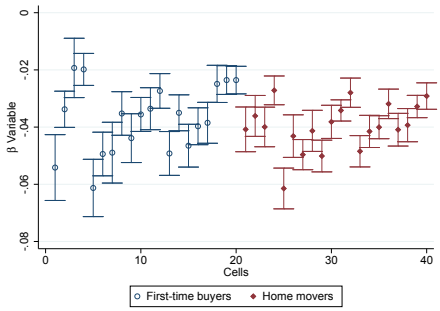
Figure E1: Demand Estimates



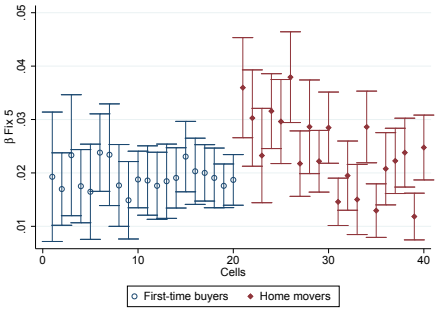
(a) Interest Rate: α_m



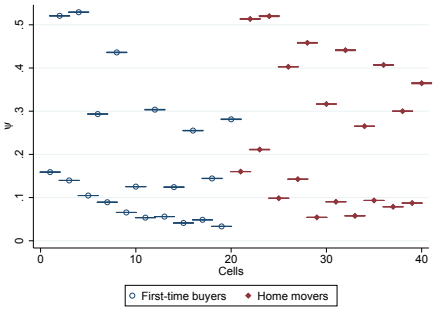
(b) High LTV: $\beta_m^{High\ LTV}$



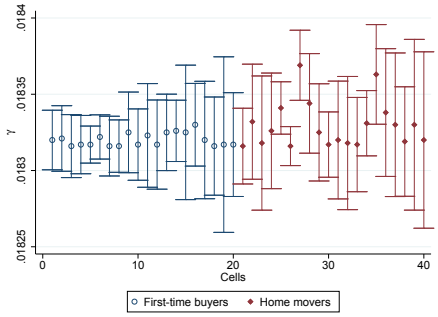
(c) Two-year Fixed: $\beta_m^{Fixed\,2}$



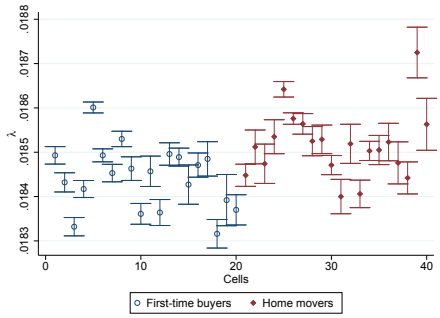
(d) Five-year Fixed: $\beta_m^{Fixed\,5}$



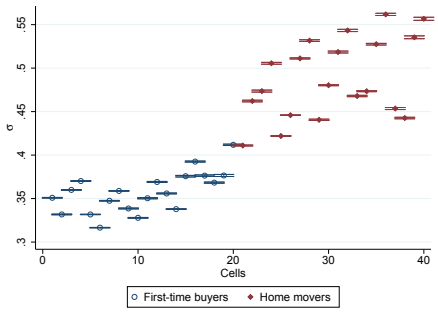
(e) Concavity in Income: ψ_m



(f) Income and Fees: γ_m



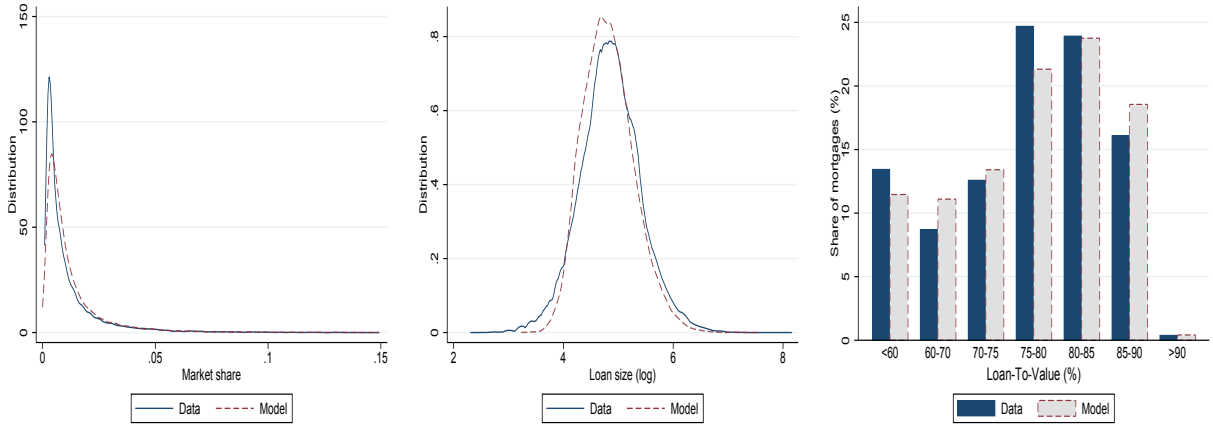
(g) Bank Branches: λ_m



(h) Standard Deviation of ζ: σ_m

Notes—The charts show the estimates of the structural demand parameters in different cells given by region, age, income, and borrower type. First-time buyer groups in blue and home mover groups in red.

Figure E2: Model Fit



Notes—The left panel displays the distribution of market shares in the data (solid line) and the model (dashed line); the middle panel displays the distribution of the log of the loan size in the data (solid line) and the model (dashed line); the right panel displays the histogram of LTV in the data (solid bars) and the model (shaded bars).

Model Fit. Figure E2 displays several plots that illustrate how the model fits the data. Overall, the fit is good, although the model slightly underpredicts that many products have a small market share (left panel) and loan size (middle panel), whereas it slightly overpredicts LTVs (right panel).

Estimated Fee-Rate Trade-off. Based on the estimated demand parameters, we consider borrowers' (approximate) annualized borrowing costs $\frac{f_{jt}}{\tau_{jt}} + r_{jt} q_{ijmt}$ and calculate the change in interest rate dr_{jt} that keeps borrowers' borrowing costs constant, given an increase in annualized fees $d\left(\frac{f_{jt}}{\tau_{jt}}\right)$:

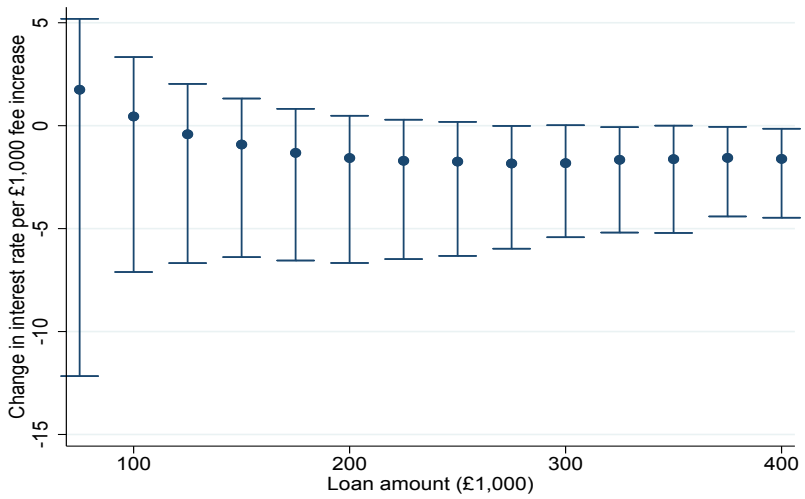
$$dr_{jt} = -\frac{\left(1 + r_{jt}\frac{\partial q_{ijmt}}{\partial\left(\frac{f_{jt}}{\tau_{jt}}\right)}\right)}{\left(q_{ijmt} + r_{jt}\frac{\partial q_{ijmt}}{\partial r_{jt}}\right)} d\left(\frac{f_{jt}}{\tau_{jt}}\right), \tag{E1}$$

where the derivatives, whose formulas are in Appendix D, draw on borrowers' heterogeneity in their loan demand (22), as the elasticities displayed in Panel B of Table 5.

Figure E3 displays the bps change in the interest rate calculated as in equation (E1) given a £1,000 increase in annualized fees $\frac{f_{jt}}{\tau_{jt}}$ for different bins of loan amounts, using the estimated parameters and the variables $q_{ijmt}, r_{jt}, f_{jt}, \tau_{jt}$ of borrowers' chosen mortgages.[26]

[26]Changes in annualized fees and interest rates as in equation (E1) would likely lead borrowers to choose a different mortgage product. Hence, Figure E3 focuses exclusively on the changes due to the loan demand (22).

Figure E3: Change in Interest Rates



Notes—This figure displays the basis-point change in interest rate calculated as in equation (E1) given a £1,000-increase in annualized fees $\frac{f_{jt}}{\tau_{jt}}$ for different bins of loan amounts. The range of each bin equals £25,000, the dot marker is the median within each bin and the vertical whiskers correspond to the range of the 10th–90th percentiles within each bin.

The figure shows that the large heterogeneity across borrowers is at odds with pure cost-minimization arguments for two main reasons. First, the median change in interest rates (the dot marker) is almost flat across the different bins of loan amounts. However, cost-minimization arguments imply that the change in the interest rate should be monotonically increasing, because borrowers should require a smaller decrease in interest rates given a fixed increase in fees as their loan amounts increase. Second, and perhaps more striking, the figure shows that the ranges of the 10th–90th percentiles (the vertical whiskers) overlap across bins, and that these large ranges shrink for the bins with large loans only. However, cost minimization implies that the range of the 10th–90th percentiles should not overlap, because borrowers should require a different range of interest rate decreases given a fixed increase in the fee as their loan amounts increase, and that the range of the 10th–90th percentiles should shrink as loan sizes increase, because each £25,000 increase in loan amount accounts for a smaller share of the total loan amount, and thus of total borrowing costs.

Demand Cross-Product Elasticities. Tables E1 and E1 display the cross-price elasticities among the 10 products with the largest market share in the first-time buyer and home mover segments, respectively.

Three main patterns emerge from these tables. First, the product with the largest cross-price elasticity with respect to the price of product 1 in the first-time buyer segment of

Table E1: Cross-Price Elasticities, First-time Buyers

	LTV Band	Dealtype	Lender	Product									
				1	2	3	4	5	6	7	8	9	10
1	80<LTV<=85	2-year fixed	1	-12.94	1.50	0.36	1.21	1.48	0.00	1.83	1.48	1.19	1.39
2	85<LTV<=90	2-year fixed	1	1.53	-10.36	0.00	0.85	1.55	0.00	1.51	1.55	0.83	1.48
3	70<LTV<=75	2-year fixed	1	0.40	0.00	-8.47	0.89	0.00	0.91	0.39	0.00	0.88	0.00
4	75<LTV<=80	2-year fixed	1	0.86	0.61	0.57	-13.25	0.60	0.31	0.84	0.60	1.14	0.53
5	85<LTV<=90	2-year fixed	9	0.96	0.98	0.00	0.52	-10.83	0.00	0.94	0.97	0.51	0.87
6	60<LTV<=70	2-year fixed	1	0.00	0.00	0.99	0.54	0.00	-5.76	0.00	0.00	0.53	0.00
7	80<LTV<=85	2-year fixed	9	1.00	0.81	0.19	0.65	0.80	0.00	-13.60	0.80	0.65	0.73
8	85<LTV<=90	2-year fixed	6	0.91	0.93	0.00	0.48	0.92	0.00	0.90	-10.86	0.47	0.89
9	75<LTV<=80	2-year fixed	9	0.47	0.33	0.32	0.64	0.32	0.18	0.46	0.32	-13.58	0.28
10	85<LTV<=90	2-year fixed	1	0.59	0.60	0.00	0.31	0.59	0.00	0.58	0.59	0.30	-10.07

Notes—This table displays the matrix of cross-price elasticities of the 10 products with the largest market share in the first-time buyer segment in 2011Q3.

Table E2: Cross-Price Elasticities, Home Movers

	LTV Band	Dealtype	Lender	Product									
				1	2	3	4	5	6	7	8	9	10
1	LTV<=60	2-year fixed	1	-2.11	0.37	0.38	0.08	0.37	0.00	0.08	0.00	0.36	0.00
2	LTV<=60	5-year fixed	3	0.28	-2.19	0.28	0.07	0.27	0.00	0.07	0.00	0.27	0.00
3	LTV<=60	2-year fixed	7	0.23	0.23	-2.24	0.05	0.23	0.00	0.05	0.00	0.22	0.00
4	70<LTV<=75	2-year fixed	1	0.03	0.03	0.03	-3.03	0.07	0.11	0.18	0.16	0.03	0.16
5	60<LTV<=70	2-year fixed	1	0.11	0.11	0.11	0.07	-2.93	0.00	0.07	0.04	0.10	0.04
6	85<LTV<=90	2-year fixed	1	0.00	0.00	0.00	0.03	0.00	-2.89	0.03	0.11	0.00	0.11
7	70<LTV<=75	2-year fixed	9	0.02	0.02	0.02	0.15	0.06	0.09	-3.05	0.12	0.02	0.12
8	75<LTV<=80	2-year fixed	9	0.00	0.00	0.00	0.11	0.03	0.10	0.11	-3.13	0.00	0.13
9	LTV<=60	2-year fixed	9	0.11	0.11	0.11	0.02	0.11	0.00	0.02	0.00	-2.27	0.00
10	75<LTV<=80	2-year fixed	1	0.00	0.00	0.00	0.10	0.03	0.09	0.10	0.12	0.00	-3.12

Notes—This table displays the matrix of cross-price elasticities of the 10 products with the largest market share in the home mover segment in 2011Q3.

Table E1 is product 7, which has the same key attributes as product 1, that is the same LTV band and the same fixation period, but it is offered by a different lender. This type of substitution is pervasive: products 2, 4, 5, 8, 9, and 10 in the first-time buyer segment, and products 1, 3, 4, 7, 8, 9, and 10 in the home mover segment display the highest cross-price elasticities with products with the same attributes but offered by a different lender. Second, for products that do not display the aforementioned feature, the highest cross-price elasticities tend to be with the price of a product offered by the same lender but in an adjacent LTV band. It is easier to discern this pattern in Table E1 about the first-time buyer segment than in Table E2 about the home mover segment, because the most popular products are more heterogeneous in the home mover segment and thus some cross-price elasticities are not reported. Third, the lowest cross-price elasticities are consistently those with respect to prices of products with very different LTV bands.

Supply. Table E3 reports the coefficient estimates of the cost equation (25) in which $\mathbb{1}\{Q_{lt}^F > 0\}$ depends on the net positive drawing stock on FLS funds in quarter t. Interestingly, the first-stage regressions are stronger than those reported in Table 6, likely because our instruments may work better in the cross-section of banks and the drawing stock exhibit less time variation the drawing flow. The point estimates of the second-stage regression coefficients confirm that FLS funds lowered lenders' funding costs.

Table E4 reports the coefficient estimates of a regression equation similar to (24) using the estimated underwriting cost a_{ij} as the dependent variable instead. We do not find any evidence that the FLS program affected underwriting costs, which provides a useful placebo test of our main analysis, because changes in lenders' funding costs due to the FLS should not affect their costs of processing mortgage applications.

Counterfactuals. Tables E5 and E6 report the counterfactual analyses of Section 7 across different borrower groups in the first-time buyer and home mover segments, respectively.

Columns (1)–(4) report the average interest rate and average origination fee paid by each borrower group, as well as their average loan amount and the number of mortgages originated in the 2011Q3 baseline market before the introduction of FLS facilities, respectively. Columns (5)–(8) report the corresponding outcomes in the counterfactual market in which the marginal costs of lenders with positive FLS drawings are 40 bps lower, as in column (4) of Table 7. Columns (9)–(12) Tables E5 and E6 report on the heterogeneity of the effect of banning fees across borrower groups in the first-time buyer and home mover segments, respectively.

Table E3: The FLS and Lenders' Costs, Alternative Definition

	FLS Flow					
	(1) OLS	(2) FS	(3) IV	(4) OLS	(5) FS	(6) IV
FLS						
Drawing stock > 0	-0.212***		-0.236***	-0.108**		-0.172*
	(0.049)		(0.091)	(0.050)		(0.093)
Excluded Instruments						
FLS Allowance (£)		0.052***			0.051***	
		(0.005)			(0.005)	
Lender Characteristics						
Sight deposits	-0.432	0.304	-0.360	-0.935	0.658	-0.729
	(0.815)	(0.418)	(0.781)	(0.704)	(0.440)	(0.690)
Time deposits	-1.158	-5.365***	-1.116	-1.520*	-4.796***	-1.388*
	(0.823)	(0.775)	(0.771)	(0.791)	(0.796)	(0.736)
Capital ratio	-0.214	-2.762***	-0.316	-2.432*	-0.664	-2.560*
	(1.318)	(0.702)	(1.388)	(1.281)	(0.669)	(1.316)
Repos	6.671***	-2.568***	6.674***	4.455***	-0.851**	4.586***
	(1.130)	(0.417)	(1.121)	(1.078)	(0.397)	(1.082)
Assets (£T)	-0.590	-0.365**	-0.634	-0.550	-0.178	-0.655*
	(0.369)	(0.170)	(0.399)	(0.354)	(0.153)	(0.383)
Product-level Costs						
Risk weights	5.373***	0.616***	5.391***	0.247	4.726***	0.599
	(0.528)	(0.097)	(0.528)	(0.964)	(0.483)	(1.040)
Swap rates	0.426***	-0.113***	0.422***	0.554***	-0.119***	0.544***
	(0.073)	(0.035)	(0.075)	(0.057)	(0.040)	(0.061)
High LTV	0.684***	-0.046***	0.683***			
	(0.057)	(0.008)	(0.057)			
Home movers	-0.316***	-0.010	-0.316***			
	(0.046)	(0.009)	(0.046)			
Variable rate	-0.224***	-0.008	-0.224***			
	(0.039)	(0.006)	(0.038)			
Fix 5 years	0.134**	0.063***	0.136**			
	(0.058)	(0.020)	(0.058)			
Selection						
Age	-0.012	0.003	-0.012	-0.006	0.001	-0.006
	(0.009)	(0.003)	(0.009)	(0.007)	(0.003)	(0.007)
Income	0.626	0.105	0.628	0.433	0.125	0.440
	(0.468)	(0.165)	(0.465)	(0.377)	(0.179)	(0.382)
Age × Income	-0.010	-0.003	-0.010	-0.006	-0.003	-0.006
	(0.012)	(0.004)	(0.012)	(0.010)	(0.004)	(0.010)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	No	No	No
Product f.e.	No	No	No	Yes	Yes	Yes
Marginal cost (mean)	3.17	0.43	3.17	3.16	0.43	3.17
F statistic			113.97			101.85
Adjusted R^2	0.78	0.89	0.78	0.86	0.90	0.86
Observations	2,796	2,796	2,796	2,791	2,791	2,796

Notes—The dependent variable is the cost $\widetilde{c}_{jt}$ of each mortgage product j in quarter t. Standard errors are clustered at the product level.

Table E4: The FLS and Underwriting Costs

	FLS Flow			FLS Stock		
	(1) OLS	(2) FS	(3) IV	(4) OLS	(5) FS	(6) IV
FLS						
Drawing flow > 0	0.360**		0.355			
	(0.159)		(0.595)			
Drawing stock > 0				0.087		0.205
				(0.236)		(0.347)
Excluded Instruments						
FLS Allowance (£)		0.026***			0.046***	
		(0.005)			(0.007)	
Product-level Costs						
Risk weights	3.809	-0.004	3.809*	3.770	0.482***	3.709
	(2.359)	(0.133)	(2.310)	(2.350)	(0.130)	(2.306)
High LTV	-0.056	0.008	-0.056	-0.049	-0.049***	-0.043
	(0.283)	(0.009)	(0.278)	(0.282)	(0.010)	(0.275)
Home movers	0.926***	-0.022	0.926***	0.918***	0.005	0.917***
	(0.212)	(0.024)	(0.205)	(0.212)	(0.015)	(0.207)
Lender Characteristics						
Sight deposits	-6.043**	1.767***	-6.026**	-5.142**	0.241	-5.448**
	(2.706)	(0.593)	(2.644)	(2.590)	(0.552)	(2.453)
Time deposits	-2.468	-2.431***	-2.461	-2.133	-4.837***	-2.332
	(2.520)	(0.870)	(2.499)	(2.652)	(0.982)	(2.464)
Capital ratio	6.400	-4.713***	6.369	4.731	-2.744***	5.259
	(6.680)	(1.127)	(7.391)	(6.279)	(0.908)	(6.651)
Repos	-5.380	1.568*	-5.362	-4.249	-2.204***	-4.353
	(3.509)	(0.892)	(3.601)	(3.339)	(0.736)	(3.341)
Assets (£T)	4.244**	0.799*	4.244**	4.379**	-0.180	4.564**
	(1.692)	(0.462)	(1.657)	(1.756)	(0.266)	(1.941)
Selection						
Age	-0.064*	-0.003	-0.064*	-0.065*	0.002	-0.066*
	(0.037)	(0.006)	(0.036)	(0.037)	(0.005)	(0.036)
Income	-2.088	-0.170	-2.089	-2.152	0.248	-2.200
	(1.806)	(0.299)	(1.773)	(1.815)	(0.258)	(1.759)
Age × Income	0.054	0.008	0.054	0.057	-0.006	0.058
	(0.046)	(0.008)	(0.045)	(0.046)	(0.007)	(0.045)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic			31.66			47.71
Adjusted R^2	0.16	0.59	0.16	0.15	0.87	0.15
Observations	1,028	1,028	1,028	1,028	1,028	1,028

Notes—The dependent variable is the underwriting cost. Standard errors are clustered at the product level.

Table E5: Effects of the FLS on First-time Buyer Groups

Region	Age	Income	Pre-FLS (2011Q3)				FLS model				FLS no fee model			
			Rate	Fee	Loan Amount	Number of Mortgages	Rate	Fee	Loan Amount	Number of Mortgages	Rate	Fee	Loan Amount	Number of Mortgages
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Aggregate			431	913	103,577	7159	374	1,016	126,321	7272	438	0	117,578	7142
			(56)	(126)	(58,826)		(57)	(186)	(77,077)		(60)	(0)	(65,128)	
London	Young	Low	401	868	119,009	430	343	872	152,975	442	410	0	148,322	429
			(51)	(145)	(52,485)		(52)	(226)	(74,275)		(64)	(0)	(60,226)	
London	Young	High	412	860	200,210	284	357	904	247,296	289	426	0	221,766	282
			(47)	(83)	(93,493)		(41)	(123)	(125,685)		(46)	(0)	(94,979)	
London	Old	Low	394	801	139,786	257	338	848	172,111	262	390	0	166,980	257
			(42)	(160)	(64,105)		(43)	(185)	(82,246)		(52)	(0)	(73,212)	
London	Old	High	398	862	253,334	294	342	870	318,930	297	415	0	272,549	292
			(57)	(133)	(144,284)		(54)	(165)	(192,156)		(55)	(0)	(140,850)	
Southern England	Young	Low	429	930	101,460	654	371	1,062	121,851	670	432	0	120,971	653
			(56)	(117)	(39,597)		(57)	(154)	(49,725)		(62)	(0)	(46,284)	
Southern England	Young	High	433	973	155,219	384	376	965	195,631	392	435	0	173,191	383
			(51)	(100)	(59,351)		(52)	(91)	(81,181)		(54)	(0)	(64,804)	
Southern England	Old	Low	397	846	111,640	370	338	852	140,189	378	394	0	132,434	370
			(49)	(168)	(43,291)		(50)	(220)	(58,382)		(62)	(0)	(53,104)	
Southern England	Old	High	404	981	185,945	473	356	908	233,504	478	421	0	206,164	472
			(50)	(204)	(92,245)		(54)	(184)	(124,159)		(47)	(0)	(92,716)	
Central England	Young	Low	445	904	79,703	414	386	1,095	94,705	421	448	0	91,155	413
			(57)	(140)	(30,768)		(58)	(161)	(38,549)		(56)	(0)	(35,340)	
Central England	Young	High	437	940	113,469	274	384	989	137,607	279	449	0	118,587	273
			(51)	(117)	(45,902)		(50)	(135)	(58,657)		(52)	(0)	(46,613)	
Central England	Old	Low	414	953	83,400	237	358	997	100,814	240	421	0	92,099	237
			(50)	(90)	(32,179)		(49)	(176)	(40,618)		(53)	(0)	(35,929)	
Central England	Old	High	413	899	139,150	344	363	983	165,420	345	424	0	154,944	344
			(48)	(124)	(66,182)		(46)	(152)	(84,437)		(57)	(0)	(72,711)	
Northern England	Young	Low	464	952	69,445	527	409	1,136	81,058	536	473	0	77,065	526
			(56)	(94)	(27,132)		(58)	(168)	(33,064)		(53)	(0)	(30,125)	
Northern England	Young	High	454	965	101,544	392	401	1,038	121,980	399	463	0	107,722	391
			(46)	(83)	(38,899)		(48)	(121)	(49,053)		(53)	(0)	(41,077)	
Northern England	Old	Low	419	842	75,534	389	360	987	91,295	394	429	0	80,891	388
			(54)	(137)	(30,402)		(54)	(169)	(38,413)		(58)	(0)	(33,110)	
Northern England	Old	High	418	919	117,108	510	366	960	144,492	514	433	0	128,181	509
			(56)	(95)	(55,040)		(56)	(121)	(73,883)		(51)	(0)	(56,259)	
Wales/Scotland	Young	Low	443	901	70,223	264	385	1,069	83,151	269	453	0	75,503	264
			(48)	(83)	(28,342)		(49)	(152)	(34,918)		(51)	(0)	(30,463)	
Wales/Scotland	Young	High	437	833	108,597	215	380	938	131,652	218	453	0	110,470	214
			(43)	(119)	(47,914)		(46)	(158)	(62,186)		(56)	(0)	(48,796)	
Wales/Scotland	Old	Low	416	897	76,996	192	357	997	92,232	195	432	0	78,539	192
			(45)	(90)	(30,627)		(43)	(127)	(37,842)		(46)	(0)	(32,101)	
Wales/Scotland	Old	High	422	998	121,676	254	369	991	151,090	255	440	0	136,196	253
			(47)	(129)	(53,539)		(48)	(111)	(73,121)		(52)	(0)	(58,457)	

Notes—Columns (1)–(4) report market outcomes for different groups of first-time buyers in the estimated model in 2011Q3. Columns (5)–(8) report market outcomes in a counterfactual market in which we reduce the costs of lenders with positive FLS drawings by 40 bps. Columns (9)–(12) report market outcomes in a counterfactual market in which we reduce the costs of lenders with positive FLS drawings by 40 bps and we do not allow lenders to charge origination fees.

Table E6: Effects of the FLS on Borrower Home Mover Groups

Region	Age	Income	Pre-FLS (2011Q3)				FLS model				FLS no fee model			
			Rate	Fee	Loan Amount	Number of Mortgages	Rate	Fee	Loan Amount	Number of Mortgages	Rate	Fee	Loan Amount	Number of Mortgages
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Aggregate			369	1,067	130,224	9458	298	1,448	157,424	9742	385	0	145,329	9441
			(55)	(243)	(95,546)		(55)	(263)	(118,478)		(50)	(0)	(99,133)	
London	Young	Low	375	1,097	140,092	294	301	1,457	168,958	308	391	0	164,501	294
			(56)	(274)	(72,389)		(56)	(355)	(94,576)		(48)	(0)	(75,447)	
London	Young	High	373	1,100	214,060	287	307	1,541	249,951	298	390	0	241,220	287
			(52)	(265)	(135,173)		(50)	(185)	(162,928)		(48)	(0)	(135,006)	
London	Old	Low	337	885	123,288	272	266	1,322	138,128	284	357	0	144,981	271
			(40)	(118)	(70,276)		(34)	(168)	(80,154)		(30)	(0)	(75,551)	
London	Old	High	338	937	220,337	273	275	1,256	268,214	282	360	0	234,049	272
			(43)	(163)	(147,370)		(38)	(184)	(185,197)		(36)	(0)	(142,521)	
Southern England	Young	Low	377	1,145	117,518	769	299	1,573	145,834	799	386	0	134,635	769
			(53)	(215)	(56,071)		(55)	(227)	(73,908)		(49)	(0)	(61,545)	
Southern England	Young	High	380	1,238	188,228	841	312	1,623	230,860	869	394	0	216,817	839
			(59)	(315)	(114,885)		(59)	(198)	(145,830)		(54)	(0)	(117,657)	
Southern England	Old	Low	339	963	89,337	725	266	1,309	109,239	747	360	0	102,863	723
			(34)	(144)	(52,458)		(34)	(170)	(66,589)		(30)	(0)	(58,186)	
Southern England	Old	High	342	960	182,352	648	275	1,418	218,771	665	360	0	197,016	647
			(51)	(201)	(129,361)		(47)	(183)	(155,757)		(46)	(0)	(127,289)	
Central England	Young	Low	392	1,077	93,939	465	318	1,518	116,656	479	403	0	100,636	465
			(57)	(236)	(47,155)		(58)	(239)	(60,270)		(52)	(0)	(49,190)	
Central England	Young	High	381	1,131	135,138	440	314	1,528	160,481	454	402	0	150,209	439
			(61)	(157)	(83,736)		(62)	(171)	(109,221)		(57)	(0)	(84,148)	
Central England	Old	Low	354	931	77,633	453	278	1,298	95,655	463	371	0	85,207	452
			(41)	(214)	(45,748)		(42)	(250)	(58,226)		(36)	(0)	(50,552)	
Central England	Old	High	349	1,095	142,257	414	283	1,479	166,128	423	368	0	164,213	412
			(51)	(220)	(106,067)		(50)	(245)	(128,364)		(44)	(0)	(109,492)	
Northern England	Young	Low	389	1,076	89,321	582	317	1,451	111,491	599	403	0	95,214	582
			(58)	(230)	(46,839)		(60)	(324)	(61,333)		(55)	(0)	(48,723)	
Northern England	Young	High	377	1,162	136,492	585	311	1,534	161,737	605	393	0	152,447	584
			(63)	(259)	(87,234)		(62)	(255)	(109,666)		(59)	(0)	(84,899)	
Northern England	Old	Low	349	888	71,204	530	279	1,238	85,436	541	373	0	76,494	529
			(42)	(128)	(42,114)		(41)	(177)	(51,254)		(35)	(0)	(45,314)	
Northern England	Old	High	345	1,054	124,798	519	281	1,425	142,912	531	370	0	141,735	517
			(45)	(270)	(93,134)		(44)	(201)	(108,436)		(43)	(0)	(94,785)	
Wales/Scotland	Young	Low	388	1,028	86,928	331	314	1,431	105,712	340	396	0	94,208	331
			(47)	(182)	(44,435)		(48)	(254)	(56,099)		(44)	(0)	(46,110)	
Wales/Scotland	Young	High	389	1,197	145,923	368	319	1,457	183,468	379	404	0	160,261	368
			(51)	(210)	(80,939)		(54)	(285)	(111,763)		(48)	(0)	(81,039)	
Wales/Scotland	Old	Low	361	940	65,659	342	283	1,222	82,568	349	374	0	70,847	342
			(37)	(130)	(38,746)		(39)	(247)	(49,235)		(32)	(0)	(41,139)	
Wales/Scotland	Old	High	355	1,064	141,656	320	285	1,336	178,634	327	372	0	157,047	319
			(40)	(282)	(91,878)		(42)	(267)	(119,236)		(38)	(0)	(97,968)	

Notes–Columns (1)–(4) report market outcomes for different groups of home movers in the estimated model in 2011Q3. Columns (5)–(8) report market outcomes in a counterfactual market in which we reduce the costs of lenders with positive FLS drawings by 40 bps. Columns (9)–(12) report market outcomes in a counterfactual market in which we reduce the costs of lenders with positive FLS drawings by 40 bps and we do not allow lenders to charge origination fees.