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Mortgage Pricing and Monetary Policy

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Abstract

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JEL Classification: E52, G51, L11

Keywords: Mortgages, monetary policy, price discrimination

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Mortgage Pricing and Monetary Policy*

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This paper provides novel evidence on lenders' mortgage pricing and how central bank policies affected it. Using the universe of mortgages originated in the U.K., we show that lenders seek to segment the market by offering two-part tariffs composed of interest rates and origination fees, and that during recent periods of unconventional monetary policy, such as the U.K.'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 structural 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 pricing and lending, and find that central bank policies increased borrower surplus and lender profits. Moreover, although origination fees allow lenders to price discriminate and capture surplus, banning fees would lower borrower surplus and aggregate welfare.

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1 Introduction

In the aftermath of the 2007-09 financial crisis, central banks around the world have sought to stimulate the economy through new policies specifically designed to revamp the credit and housing markets. These include the U.S. 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. A 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, the literature has identified several frictions in the mortgage market that could alter the transmission of monetary policy to credit markets and to 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 U.K. 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 U.K. lenders. A key contribution of our paper is our examination of a novel channel that affects the transmission of central bank policies to heterogeneous households via credit markets: 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 U.K. 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 U.K. mortgage market, such as posted rates and fees equal across borrowers, and mortgages with fixed interest rates for a relatively short (e.g., 2 years) period only, which encourage borrowers to remortgage frequently and, as a result, generate large fee income for lenders.

Moreover, these rich data allow us to provide new evidence on lenders' market segmentation and pricing strategies, most notably their pervasive use of menus with two-part tariffs

that combine (fixed) origination fees and interest rates. The pricing literature shows that indirect (i.e., second-degree) price discrimination through menus of two-part tariffs allow 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 increase their profits.

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 descriptive 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, who may have different sensitivities to interest rates and origination fees, make a discrete choice of the optimal mortgage product and a continuous choice of the 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. 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 that are 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 (2020) and Robles-Garcia (2020), 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 slightly more sensitive to interest rates than to origination fees, most notably lower-income households with a younger head. 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) marginal 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 U.K. lenders (Churm, Joyce, Kapetanios, and Theodoridis, 2021).[1]

Nevertheless, 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 use demand-side instruments that exploit an institutional feature of U.K mortgage markets: borrowers' predictable demand for remortgaging. As we state above and explain in greater detail in Section 3, U.K. mortgages feature a relatively short fixation period, in the most typical case 2 years, after which most borrowers refinance (Belgibayeva, Bono, Bracke, Cocco, and Majer, 2020; Cloyne, Huber, Ilzetzki, and Kleven, 2019). Hence, in any given quarter, the volume of mortgages that lenders originated approximately 2 years prior should affect lenders' expectation of their demand for internal refinancing, which may require new funds, for example because of cash-out refinancing. Thus, higher expected demand for remortgaging should affect lenders' decisions to draw on FLS funds, but it should plausibly be uncorrelated with unobservable components of their marginal costs in a given quarter.

Our IV estimates suggest that the FLS led to a reduction in lenders' funding costs by approximately 70 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 20 percent. Our estimated magnitude of approximately 70 bps fits 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 U.K.

[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).

lenders.

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 40 bps, but increased posted fees by approximately £120. 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 that the FLS boosted aggregate lending by more than 30 percent.

We also perform an extensive analysis across different demographic groups of different borrower outcomes and welfare, which allows us to understand the welfare 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 the South East England, enjoyed the largest gains in consumer surplus due to the FLS, because the associated decrease in interest rates favored areas with the highest concentration of borrowers with larger loans. Nevertheless, within these (rich) areas, low-income households also experienced a large increase in consumer surplus, due to their higher sensitivity to interest rates in the midst of their decline.

Finally, we use our model to understand the contribution of indirect price discrimination through two-part tariffs to market outcomes and welfare. Specifically, we ban lenders from charging origination fees. In such a counterfactual scenario with zero origination fees, lenders charge higher interest rates to offset the drop in profits due to the ban on fees. Naturally, lenders' profits decline but consumer surplus also decreases, indicating that they benefit from this market segmentation and price discrimination increases surplus. In the context of our main research question, this finding demonstrates that two-part pricing strategies provide a mechanism through which household heterogeneity amplifies the effects of monetary policy.

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 motivating evidence for and empirical regularities of the U.K. 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 model derivations, and further empirical results.

2 Related Literature

This paper contributes to several strands of the literature. First, several papers study policy interventions introduced in the aftermath of the financial crisis in credit and mortgage markets. Many important contributions focus on U.S. 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 borrowers' leverage; Agarwal, Amromin, Ben-David, Chomsisengphet, Piskorski, and Seru (2017) and Agarwal, Amromin, Chomsisengphet, Landvoigt, Piskorski, Seru, and Yao (2020) examine how large-scale debt relief programs of the U.S. government affect mortgage restructuring and the refinancing of borrowers with large mortgage debt who risk of foreclosure.

Particularly related to our paper is Buchak, Matvos, Piskorski, and Seru (2020), who build a model of competition in the U.S. mortgage market between banks and shadow banks, and examine how quantitative easing affects this competition and market outcomes. Our paper shares with that of Buchak, Matvos, Piskorski, and Seru (2020) attention to lender competition with heterogeneous borrowers. However, we tailor our quantitative model to the U.K. mortgage market (in which shadow banks and mortgage 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 have examined 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 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 (2020) and Robles-Garcia (2020) develop and estimate equilibrium models of the U.K. 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 (2020) and Robles-Garcia (2020), 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 a recent and emerging literature that uses structural equilibrium models to study retail financial

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

markets, such as Mexican privatized pension markets (Hastings, Hortaçsu, and Syverson, 2017); Canadian mortgage markets (Allen, Clark, and Houde, 2019); U.S. car loan markets (Einav, Jenkins, and Levin, 2012; Grunewald, Lanning, Low, and Salz, 2020); and U.S. retail deposit markets (Aguirregabiria, Clark, and Wang, 2019; Egan, Hortaçsu, and Matvos, 2017), among others.[3]

Third, our analysis joins a growing research effort to understand the aggregate and distributional impact of macroeconomic policies on credit markets. Some recent empirical papers uncover pervasive heterogeneity in the effects of monetary policy on household borrowing (Di Maggio, Kermani, and Palmer, 2020; Greenwald, 2018) and corporate lending (Bahaj, Foulis, Pinter, and Surico, 2019; Greenwald, Krainer, and Paul, 2020). Our paper contributes to this macroeconomic literature by documenting the extensive heterogeneity of U.K. mortgage borrowers in their interest-rate sensitivity, and how lenders exploit such heterogeneity to segment the mortgage market. In doing so, we propose that lenders' price discrimination strategies are a novel aspect of the transmission of central bank policies.

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, since we study how central bank policies that affect lenders' costs affect their price discrimination strategies. Moreover, as we argue in Section 3, U.K. 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.[4]

[3] As our paper does, Aguirregabiria, Clark, and Wang (2019) also model (some of) banks' funding and lending simultaneously. However, we focus on funding from central banks and exploit rich micro-data on U.K. mortgages, whereas Aguirregabiria, Clark, and Wang (2019) examine retail deposits and mortgage lending with more aggregate U.S. data.

[4] 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; and (2) telecommunication markets feature periodic subscription contracts, whereas mortgage markets feature one-off choices, and thus have differential roles for consumer learning.

3 Data and Motivating Patterns

Our analysis exploits a rich database that reports all mortgage originations in the U.K. We use these data to study the market for first-time buyers during the period 2010-2014. We focus on first-time-buyers for two main reasons. First, home movers' and remortgagers' *new* mortgage choice depends on their *existing* mortgages, which we do not observe precisely in our datasets. Second, first-time buyers are the mortgage borrowers with the highest leverage, and thus they are potentially more responsive to the central bank policies conducted during our sample period.

We complement our main database on mortgage originations with additional data on the mortgage market, 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), constructed by the Financial Conduct Authority (henceforth FCA), collects all mortgage originations and reports the main contract characteristics: 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, remortgager); and property characteristics: location and transaction price.

Despite the richness of the PSD, it has two limitations for our purposes. First, it reports mortgage fees since 2015 only, which is after the introduction of the Bank of England's Funding for Lending Scheme in 2012. We overcome this limitation. since PSD reports the main characteristics of each origination, such as the lender, 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 (2020), and Robles-Garcia (2020) establish that the U.K. mortgage market features differentiated mortgage products and posted prices at the national level.[5] Hence, we define a product type as a combination of three non-price characteristics: (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

[5]Borrower-specific pricing, which is common in the U.S. mortgage market, is extremely limited in the U.K. market; similarly, 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. Appendix C provides more evidence on mortgage pricing in the PSD.

and a pair of associated rate/fees. Thus, given a product type and an interest rate observed in the PSD, we can recover the corresponding origination fee in the Moneyfacts dataset. Appendix A reports more details on the merging of these two datasets and imputation of the fee, as well as other missing characteristics, in the PSD.

Second, the PSD does not report 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 characteristics to construct the choice set of each borrower. Specifically, we define a market as a combination of a geographic areas (five areas: London, Southern England, Central England, Northern England, and Wales and Scotland) and demographic characteristics (four categories based on income and age, below and above their respective aggregate medians), yielding a total of 20 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. 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.

Moneyfacts. The Moneyfacts Residential Mortgage Analyzer reports the near universe of mortgage products offered in the U.K. For each mortgage product, we collect the main observable characteristics: the lender that offers it, the LTV band, maximum advance and maximum loan-to-income ratio, 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.

Funding for Lending Scheme and Lenders' Balance Sheet Data. The Bank of England and the U.K. 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 costs of FLS funds to borrowers by lowering interest rates on loans and mortgages. Both the quantity and the price of these funds depend on the amount of bank lending.[6] Appendix B provides more institutional

[6]In response to the economic crisis triggered by the global pandemic of 2020, the FLS has been revamped in the U.K. Similar schemes were also launched during 2020 in Australia, New Zealand, Saudi Arabia,

details on the FLS program.

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

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 Mortgage Products and Pricing

The goal of this subsection is to use our rich datasets to document the main empirical patterns with respect to how U.K. lenders design their national menus of mortgage products to segment the market and how two-part pricing contributes to this segmentation, in a typical second-degree price discrimination strategy. Moreover, the literature on price discrimination emphasizes that any segmentation strategy arises because of the heterogeneity of household demand (Varian, 1989). Hence, we document some relevant observable heterogeneity across borrowers, as well as the heterogeneity of their choices.

These data also allow us to describe some relevant institutional features of U.K. mortgage markets, such as posted rates and fees that do not vary across borrowers, as well as mortgages with fixed interest rates for a relatively short (e.g., 2 years) time only, and recurring borrower refinancing.

(1) A large number of mortgage products. The Moneyfacts data are particularly well suited for illustrating the richness of the mortgage products U.K. lenders offer to first-time buyers. Table 1 reports some interesting statistics to this end.

The first row of Panel A reveals that in a typical month, there are more than 500 residential mortgage products are on offer in the U.K. We emphasize that lenders offer (almost) identical menus in all U.K. regions they serve, hence this large number of products is not

Sweden, Taiwan, and the U.S. 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.

Table 1: Summary Statistics from Moneyfacts

	Mean	Sd	Median	p10	p90
Panel A: Products					
Products by month (#)	569.75	98.93	562.00	434.00	724.00
Product types by month (#)	178.24	21.88	177.00	151.00	208.00
Products by type/month (#)	3.20	3.11	2.00	1.00	7.00
Lenders by month (#)	10.92	0.28	11.00	11.00	11.00
Products by lender/month (#)	52.20	42.06	43.00	16.00	94.00
Product types by lender/month (#)	16.33	4.94	16.00	10.00	22.00
Panel B: Prices					
Rate	4.03	1.09	3.90	2.69	5.59
Fee	656.67	545.36	499.00	0.00	1295.00

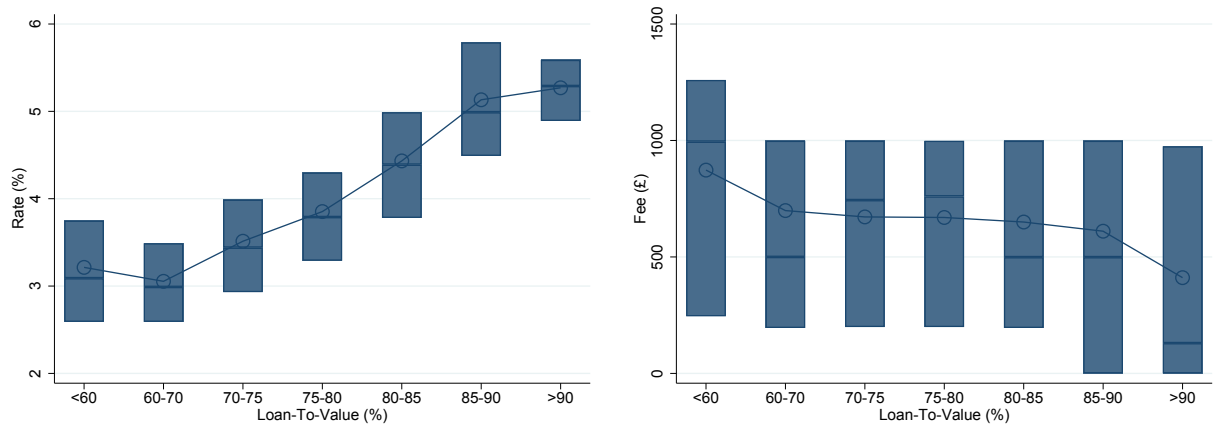
Notes: Summary statistics of the main mortgage products available to first-time buyers in the Moneyfacts database. Sample: 2010-2014.

an artifact of the duplication of products across regions, though of course some regional lenders may have a local reach only. The second row reports that the number of product types per month equals approximately 180 (we remind readers that we define a product as the combination of a product type and the associated interest rate/origination fee pair). The most typical product type is a 2-year fixed mortgage, which means that borrowers face an interest rate that is fixed for 2 years and thereafter reverts to a higher level (called the standard variable rate). Hence, this dual-rate structure implies that approximately 70 percent of borrowers refinance exactly at the expiration of their fixation period, as documented by Cloyne, Huber, Ilzetzki, and Kleven (2019) and Belgibayeva, Bono, Bracke, Cocco, and Majer (2020). This frequent remortgaging activity implies that fees account for a large share of lender revenues, since most borrowers pay them every 2 years. The third row reveals that the typical product type exhibits approximately three multiple fee/rate quotes—e.g., a high-fee/low-rate product, a medium-fee/medium-rate product, and a low-fee/high-rate product.

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, often called the "Big 6," have a national presence, whereas some other lenders, such as building societies, tend to have a narrower regional reach. On average, a lender offers approximately 50 mortgage products and 17 product types, with some lenders offering more than 90 mortgage products in a given month.

Panel B reports initial rates and origination fees, which display large variations across products. More specifically, the average interest rate equals 403 bps, the standard deviation equals 109 bps, and the difference between the 90th and the 10th percentile of the initial in-

Figure 1: Mortgage Pricing



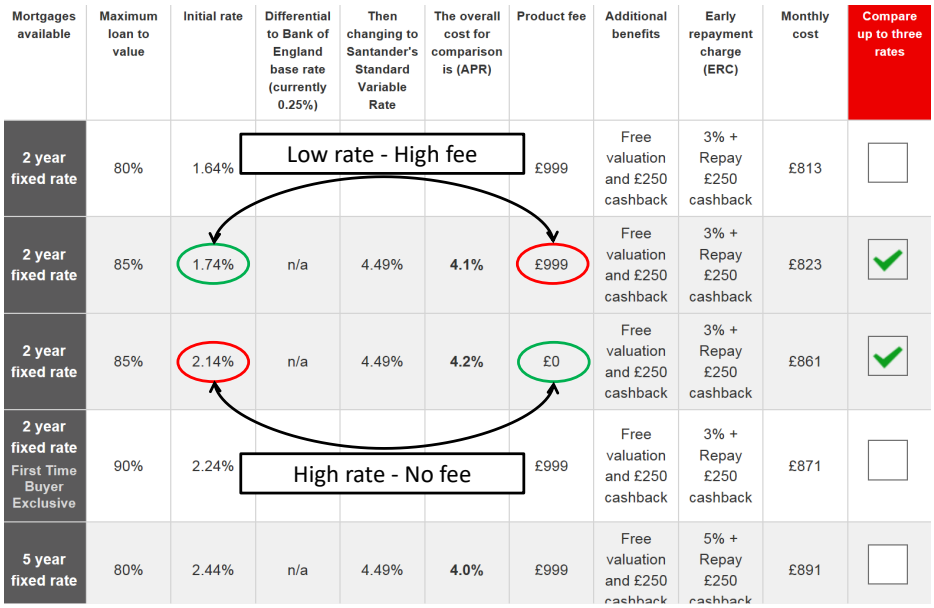
Notes: The left panel displays the average and the interquartile range of initial interest rates, the right panel displays the average and the interquartile range of origination fees for all products in each LTV band based on the Moneyfacts dataset.

terest rates equals 290 bps. The average origination fees equals £656, the standard deviation equals approximately £550, and the difference between the 90th and the 10th percentile is approximately £1,300.

The variation in interest rates across products is mostly due to differences in the maximum LTV band, which captures lenders' default risk, and, to a lesser extent, in the fixation period (e.g., 2-year fixed, 5-year fixed, or variable rate), which captures lenders' interest-rate risk. Specifically, the left panel of Figure 1 displays how initial interest rates vary across mortgage loans with different maximum LTV bands. There are notable jumps in rates across mortgages with different maximum LTV bands, especially above 80 percent. This confirms that U.K. lenders adjust interest rates across LTV bands to account for default risk, as described above. Moreover, the right panel of Figure 1 shows that in sharp contrast to interest rates, origination fees exhibit only slight variation across LTV bands, and thereby suggests that lenders mainly use them to extract consumer surplus, as in a typical price-discrimination strategy.

(2) The prevalence of two-part pricing. Another reason for the variation in interest rates is two-part pricing. Figure 2, from the website of a major lender, displays a typical example of a lender offering the same product type—i.e., an identical fixed term of 2 years, 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

Figure 2: Product Definition



Mortgages available	Maximum loan to value	Initial rate	Differential to Bank of England base rate (currently 0.25%)	Then changing to Santander's Standard Variable Rate	The overall cost for comparison is (APR)	Product fee	Additional benefits	Early repayment charge (ERC)	Monthly cost	Compare up to three rates
2 year fixed rate	80%	1.64%				£999	Free valuation and £250 cashback	3% + Repay £250 cashback	£813	☐
2 year fixed rate	85%	1.74%	n/a	4.49%	**4.1%**	£999	Free valuation and £250 cashback	3% + Repay £250 cashback	£823	☑
2 year fixed rate	85%	2.14%	n/a	4.49%	**4.2%**	£0	Free valuation and £250 cashback	3% + Repay £250 cashback	£861	☑
2 year fixed rate First Time Buyer Exclusive	90%	2.24%				£999	Free valuation and £250 cashback	3% + Repay £250 cashback	£871	☐
5 year fixed rate	80%	2.44%	n/a	4.49%	**4.0%**	£999	Free valuation and £250 cashback	5% + Repay £250 cashback	£891	☐

Notes: Snapshot from the website of a large lender on mortgages offered with a fixed initial rate period of 2 years.

rate.

The Moneyfacts data allow us to precisely quantify the relationship between rates and fees within a product type. Hence, we run 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 quarter t; f_{jkt} is the corresponding fee; χ_{kt} are product type-quarter 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 and the second with an indicator variable equal to one for products with zero fees and zero otherwise.

Table 2 reports the coefficient estimates. The top panel refers to the baseline model with continuous fees. The first column reports that a £1,000 higher origination fee corresponds to a 27 bps lower interest rate within the same product type-quarter pair. Other columns report coefficients obtained on different subsamples of the data—i.e., for different product

Table 2: Relation Rates-Fees

	Baseline	Heterogeneity					
		(Fix)	(Var)	(<75)	(>75)	(Big 6)	(Other)
Fee (.000)	-0.274***	-0.292***	-0.210***	-0.273***	-0.278***	-0.263***	-0.283***
	(0.019)	(0.018)	(0.043)	(0.022)	(0.026)	(0.027)	(0.022)
R^2	0.95	0.95	0.90	0.92	0.94	0.95	0.94
Zero Fees	0.328***	0.330***	0.322***	0.342***	0.258***	0.333***	0.325***
	(0.021)	(0.021)	(0.035)	(0.022)	(0.034)	(0.025)	(0.028)
R^2	0.94	0.95	0.90	0.92	0.93	0.95	0.94
Product-Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	55,611	41,179	14,432	46,320	9,291	24,623	30,988

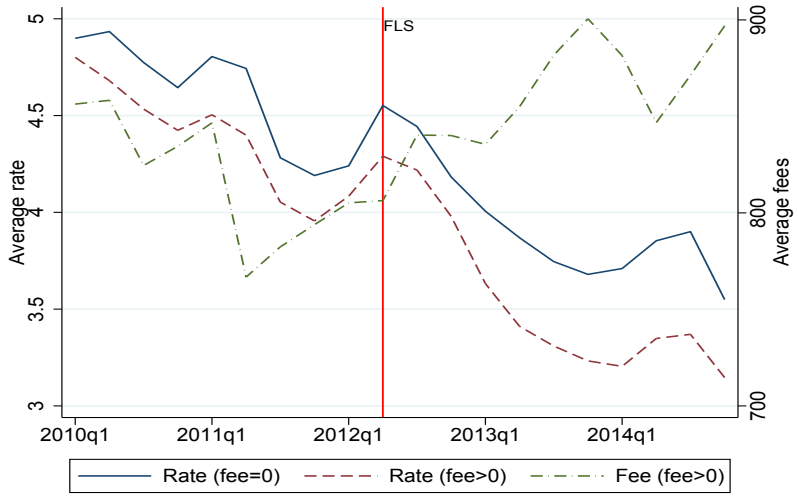
Notes: The top panel reports the estimates from equation (1) using fees as a continuous explanatory variable. The bottom panel reports the estimates from equation (1) using an indicator variable equal to one if fees are zero, and zero otherwise, as explanatory variable. Standard errors are double clustered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

types depending on the interest-rate type (fixed or variable); maximum LTV (below or above 75 percent); and lender (Big 6 or not). The result is remarkably stable across subsamples. The bottom panel of Table 2 reports the coefficient estimates of equation (1) when we use as explanatory variable an indicator variable equal to one for products with zero fees and zero otherwise. The estimates imply that a product with zero fees tends to be offered at an interest rate that is on average 33 bps higher than an identical product type but with a positive fee. All estimates on different subsamples show limited heterogeneity.

(3) The FLS and two-part pricing. The FLS program started in July 2012 to encourage lending to firms and households by decreasing lending rates through cheap funding costs, as we detail in Appendix B. The scope of the scheme narrowed over time and, since February 2014, focused on lending to small and medium enterprises only, thereby excluding mortgage lending.

Figure 3 is a starting point in understanding the effect of the FLS program on the mortgage market. It 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 entire sample period, and this decrease, which was already ongoing before the start of the FLS in July 2012, may have accelerated after the FLS introduction. Moreover, before 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 program, the gap between the two rates widens: The decline in interest rates is

Figure 3: FLS and Mortgage Pricing



Notes: The solid line displays the average interest rate on products with no fees, the dashed line the average interest rate on products with positive fees, and the dashed-dotted line the average fees on products with positive fees.

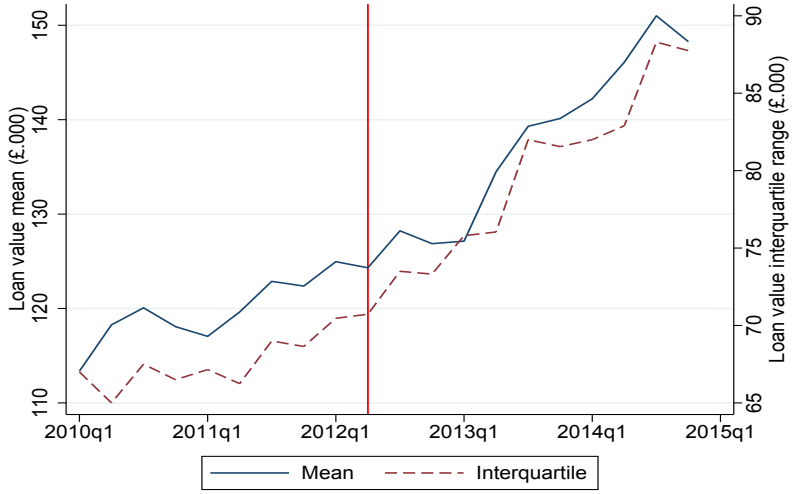
substantially smaller for no-fee products than for positive-fee ones, with the difference in rates between the two sets of products moving from an average of about 10 bps in the first quarter of 2012 to an average of around 50 bps by the first quarter of 2014. The dashed-dotted line portrays the time-series evolution of average fees for products with positive fees only. These fees were quite stable before introduction of the FLS program, but increased by approximately £100 afterward.

Overall, the patterns in Figure 3 suggest that after the introduction of the FLS program, lenders adjusted interest rates downward to attract borrowers and increased origination fees for some of their products, presumably to extract consumer surplus and increase profits.

(4) Borrowers' heterogeneity and choices. Product differentiation and price discrimination are the outcomes of suppliers' attempts to segment a market composed of consumers with large observable and unobservable heterogeneity in preferences and/or budget constraints (Eaton and Lipsey, 1989; Varian, 1989). For example, in mortgage markets borrowers with different incomes may choose mortgages with different maximum LTV bands and different loan sizes. Similarly, borrowers with different degrees of risk aversion may prefer different durations of their initial fixation periods.

Differential house prices across geographic markets are a core dimension of heterogeneity in mortgage markets. Naturally, differential house prices map onto heterogeneous loan sizes. Figure 4 attests to these differences in the PSD data. Specifically, the solid line shows

Figure 4: Dynamics of the Average and the Interquartile Range of Loan Values



Notes: The solid line shows the average loan size for first-time buyers in 2010-2014 in the PSD (left scale). The dashed line displays the interquartile range of the loan size distribution for first-time buyers in 2010-2014 in the PSD (right scale).

that the average loan size of first-time buyers is steadily increasing in the period 2010-2014, since house prices rose during our sample period, most notably starting from the fourth quarter of 2012. 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 the South East England than those in other areas.

Differences in house prices and thus loan sizes, as well as any other observable and unobservable heterogeneity, determine borrowers' choices between high-fee/low-rate and low-fee/high-rate products. Of course, households with larger loans most likely minimize their borrowing costs by choosing high-fee/low-rate mortgages. Consistent with this cost-minimization argument, Figure 5 shows that the fraction of borrowers who choose no-fee products declines as borrowers' loan amounts increase. However, if borrowers were choosing purely based on this cost-minimization argument, we would perhaps expect a steeper decline than that displayed in Figure 5—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.

Our calculations show that approximately 51 percent of borrowers choose the mortgage that minimizes their borrowing costs over the fixation period when a mortgage with identical non-price characteristics (e.g., same lender, LTV band, fixation period) was available; 43 percent 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 6 percent choose a product with a higher interest rate and lower fee when a product with a lower interest rates and a higher fee would have minimized 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 account more than fees for borrowers' choices.

Our data do not allow us to explore the exact reasons for these choices that do not minimize borrowing costs. They may arise from borrowers' behavior, such as limited search, mistakes, and behavioral biases (Agarwal, Ben-David, and Yao, 2017; Woodward and Hall, 2012); unobservable mortgage attributes (Gurun, Matvos, and Seru, 2016); lenders who steer some unsophisticated borrowers toward more expensive products (Guiso, Pozzi, Tsoy, Gambacorta, and Mistrulli, 2021); and the interaction between borrowers' search and lenders' application approval (Agarwal, Grigsby, Hortaçsu, Matvos, Seru, and Yao, 2020).[7] Hence, our model will feature observable and unobservable borrower heterogeneity, as well as observable and unobservable mortgage/lender attributes, to capture in a rich and flexible way borrowers' choice of mortgage products from lenders' menus. Estimates of borrowers' sensitivity to interest rates and fees, as well as their heterogeneity, will be important inputs for our evaluation of how the lenders' price discrimination strategies affect the transmission of central bank policies.

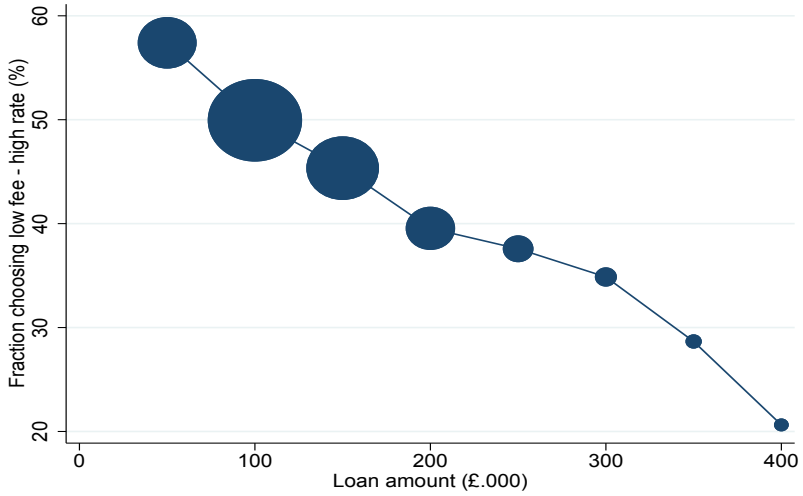
3.2 Summary Statistics

Table 3 reports summary statistics for the 2010-2014 PSD data we use to estimate our model. The estimation sample consists of approximately 85,000 mortgages for first-time buyers. Panel A reports the main demographic characteristics of these borrowers. The average first-time buyer has a gross annual income of approximately £42,000 and an average age of 30 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 approximately 70 products. Appendix A reports more details on the exact construction of our estimation dataset, which also entails some aggregations of mortgage products with very low market shares (less than 0.1 percent).

[7] Cloyne, Huber, Ilzetzki, and Kleven (2019) note that U.K. 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 5: Fee Choice and Loan Amounts



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

Panel C reports statistics on borrowers' choices. The loan amount has an average of approximately £135,000 and displays considerable heterogeneity: the standard deviation equals £76,000. The average loan has an LTV of 82, a loan-to-income of 3.43, and a maturity of 28 years. National Big 6 lenders originate more than 80 percent of mortgages for first-time buyers. The average initial rate is 420 bps, and the heterogeneity of interest rates is quite high—the standard deviation is 92 bps—since the heterogeneity of LTVs maps onto the heterogeneity of interest rates, as Figure 1 shows. Average origination fees amount to approximately £660.

Overall, our datasets allow us to provide a thorough description of U.K. mortgage markets. Market features, such as the large number of mortgage products and posted prices, prompt us to use a discrete-choice model in which lenders offer differentiated mortgage products and heterogeneous households choose among them. Moreover, the pervasiveness of products with multiple rate-fee pairs suggests that lenders are actively seeking to price discriminate across borrowers using two-part pricing. This is a novel and interesting aspect of mortgage pricing to study. The vast majority of previous studies on mortgage markets have focused on the interest rate borrowers pay. However, origination fees can represent an important component of the total cost of borrowing and the profits of lenders, most notably since refinancing is frequent in the U.K. market, and thus most borrowers pay the origination

Table 3: Summary Statistics

	Mean	Sd	Median	p10	p90
Panel A: Demographics					
Gross income (£, 000)	42.12	39.35	35.61	20.50	67.31
Age (years)	30.11	6.60	29.00	23.00	39.00
London	0.17	0.37	0.00	0.00	1.00
South	0.27	0.44	0.00	0.00	1.00
Middle	0.18	0.38	0.00	0.00	1.00
North	0.25	0.44	0.00	0.00	1.00
Wales & Scotland	0.13	0.34	0.00	0.00	1.00
Panel B: Choice set					
Lender per market	10.46	0.64	11.00	10.00	11.00
Product per market	68.12	10.65	69.00	53.00	82.00
Panel C: Choices					
Loan amount (£, 000)	134.65	76.48	117.00	67.15	214.65
Loan-to-value	82.21	7.48	84.99	71.43	90.00
Loan-to-income	3.43	1.98	3.39	2.22	4.56
Maturity (years)	28.74	5.51	30.00	24.00	35.00
Big 6	0.81	0.39	1.00	0.00	1.00
Fixed rate	0.93	0.26	1.00	1.00	1.00
Rate	4.22	0.92	4.14	3.19	5.69
Fee	661.76	486.80	499.00	0.00	1260.00

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

fee frequently (Cloyne, Huber, Ilzetzki, and Kleven, 2019).[8] In turn, incorporating fees may provide a more complete picture of the transmission mechanism of central bank policies on lenders and borrowers.

4 A Structural Model of the Mortgage Market

The descriptive evidence in the previous section depicts some intriguing pricing patterns, which raise several interesting questions. Specifically, how do borrowers choose among rate-fee pairs? How does lender pricing depend on their costs, as well as 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

[8]Two additional features of U.K. mortgage markets are relevant for our subsequent analysis: (1) Mortgages include large prepayment penalties for repayment before the end of the fixation period, and thus prepayment is extremely rare (Cloyne, Huber, Ilzetzki, and Kleven, 2019). (2) Mortgage payments for owner-occupied properties are not tax deductible.

manner. Moreover, the previous descriptive analysis prompts us to model borrowers' choices from lenders' menus 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, indexed by i, who decide to either buy a property or rent a (possibly different) property. Renting gives households the value of the outside option $j = 0$. Conditional on buying a property in market m, households 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 income.

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

$$V_{ijmt} = \bar{V}_{ijmt}\left(Y_i, X_j, r_{jmt}, f_{jmt}, B_{ijmt}, \zeta_i, \xi_{jmt}; \theta_m\right) + \varepsilon_{ijmt}, \tag{2}$$

where Y_i is household income; r_{jmt} is the rate and f_{jmt} is the origination fee of product j in market m in quarter t; X_j are time-invariant product characteristics, such as the rate type, lender, and maximum LTV; B_{ijmt} is the branch network of the lender offering product j in the location of household i; ζ_i captures borrowers' unobserved characteristics, such as wealth, risk aversion, and housing preferences; ξ_{jmt} captures unobservable product characteristics that affect the utility of all borrowers for product j in market m and period t; ε_{ijmt} is an idiosyncratic shock; and θ_m collects the demand parameters common to all borrowers in market m.

If the household rents ($j = 0$), it enjoys the utility of the outside option:

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

which depends on household income Y_i and unobserved preferences ζ_i, as well as on the idiosyncratic shock ε_{i0mt} and parameters θ_m.

Following Benetton (2020), 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 renting a

property. 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

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

From the chosen product, we can derive the optimal loan amount q_{ijmt} using Roy's identity:

$$q_{ijmt} = -\frac{\frac{\partial V_{ijmt}}{\partial r_{jmt}}}{\frac{\partial V_{ijmt}}{\partial Y_i}} = q_{ijmt}(Y_i, X_j, r_{jmt}, f_{jmt}, \zeta_i, \xi_{jmt}; \theta_m). \tag{5}$$

Equations (4) and (5) uniquely define borrowers' product and loan demand, respectively, given their preferences and mortgage characteristics. In practice, equation (5) anticipates one exclusion restriction we impose: The lender's network of branches B_{ijmt} affects the utility of a specific mortgage product—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 vast majority of U.K. mortgages have a discounted variable or fixed rate, which revert to a higher standard variable rate at the end of the fixation period. Hence, borrowers have strong incentives to refinance the mortgage with a new loan when the fixation period terminates (Cloyne, Huber, Ilzetzki, and Kleven, 2019). We focus on revenues and pricing at origination, and leave to future research the analysis of retention pricing. Hence, lenders' main revenues are the net interest income from the monthly payments and the initial origination fee.

Given the demand system and borrowers' refinancing after the initial fixation period, the 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_{jmt} 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 $\frac{f_{jmt}}{\tau_{jmt}}$ and interest income $r_{jmt}q_{ijmt}$. Given borrowers' refinancing at the end of the fixation period τ_{jmt}, 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. Lenders' mortgage business incurs three types of costs. First, issuing each mortgage entails a fixed cost a_{jmt} that captures, among others, the administrative costs of processing mortgage applications. Second, mortgage lending requires variable costs to cover the risks of each mortgage product j in quarter t, such as any interest-rate risk deriving from a maturity mismatch between lenders' liabilities and the specific mortgage product, or default risk capital requirements. We assume that these costs have a constant marginal cost c^o_{jt}. Third, lenders have funding costs that depend on their total assets A_{lt}, including the mortgages issued in quarter t. Funding costs depend on lenders' liabilities, and most notably on the size of their retail deposits.

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

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

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. $C^f_{lt}\left(A_{lt}\right)$ denotes lenders' expected funding costs, increasing in total assets A_{lt}. Moreover, we adjust the application costs for the fixation periods τ_{jmt} in the cost function (7) as we did in the case of origination fees f_{jmt} in the revenue function (6).

Introduction of the FLS potentially changes lenders' 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.[9]

[9] In principle, marginal costs could increase if the wholesale funding becomes more expensive for lenders who access the FLS facilities. In practice, it did not happen (Churm, Radia, Leake, Srinivasan, and Whisker, 2012).

More formally, total $C_{lt}^f(\cdot)$ and marginal funding costs $c_{lt}^f(\cdot)$ satisfy

$$C_{lt}^f(A_{lt}) \leq C_{lt}'^f(A_{lt}) \qquad \text{if } Q_{lt}^{FLS} > 0, \tag{8}$$

$$c_{lt}^f(A_{lt}) \leq c_{lt}'^f(A_{lt}) \qquad \text{if } Q_{lt}^{FLS} > 0, \tag{9}$$

where $C_{lt}'^f(\cdot)$ and $c_{lt}'^f(\cdot)$ denote the total and marginal funding costs, respectively, 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:

$$\max_{\mathbf{r}_{lt},\mathbf{f}_{lt}} \Pi_{lt}(\mathbf{r}_t, \mathbf{f}_t) = R_{lt}(\mathbf{r}_t, \mathbf{f}_t) - C_{lt}\left(\mathbf{s}_{lt}(\mathbf{r}_t, \mathbf{f}_t), \mathbf{q}_{lt}(\mathbf{r}_t, \mathbf{f}_t)\right), \tag{10}$$

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 U.K. 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:

$$\begin{aligned}\frac{\partial \Pi_{lt}}{\partial r_{jt}} =& \sum_m \sum_i s_{ijmt} q_{ijmt} + \sum_m \sum_i s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} (r_{jt} - mc_{jt}) \\ &+ \sum_m \sum_{k \in J_{lmt}} \sum_{i \in I_{mt}} \frac{\partial s_{ikmt}}{\partial r_{jt}} \left(\frac{f_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt} - mc_{kt}) \right) = 0,\end{aligned} \tag{11}$$

where $mc_{jt} = c_{jt}^o + c_{lt}^f$ denotes the composite marginal cost on product j. The summations aggregate households and markets at the product level in a quarter. The first term gives the additional profits from the higher rate on the quantity sold; the second term captures the changes in loan demand from a higher rate; and the third term collects the impact of a higher rate on the choice probability for all products J_l offered by lender l.

Solving for the optimal interest rate yields

$$r_{jt}^{*} = \overbrace{mc_{jt}}^{\text{Marginal cost}} - \frac{\overbrace{\sum_m \sum_i s_{ijmt} q_{ijmt}}^{\text{Mark-up}}}{\sum_m \sum_i \left(q_{ijmt} \frac{\partial s_{ijmt}}{\partial r_{jt}} + s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} \right)} - \frac{\overbrace{\frac{f_{jt}^{*} - a_{jt}}{\tau_{jt}} \sum_m \sum_i \frac{\partial s_{ij}}{\partial r_j}}^{\text{Net Fee Income}}}{\sum_m \sum_i \left(q_{ijmt} \frac{\partial s_{ijmt}}{\partial r_{jt}} + s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} \right)}$$
$$\underbrace{- \frac{\sum_m \sum_{k \neq j \in J_{lmt}} \sum_i \frac{\partial s_{ikmt}}{\partial r_{jt}} \left(\frac{f_{kt}^{*} - a_{kt}}{\tau_{kt}} + q_{ikmt}(r_{kt}^{*} - mc_{kt}) \right)}{\sum_m \sum_i \left(q_{ijmt} \frac{\partial s_{ijmt}}{\partial r_{jt}} + s_{ijmt} \frac{\partial q_{ijmt}}{\partial r_{jt}} \right)}}_{\text{Other products}}. \tag{12}$$

Note that if there are no fees and no application costs, all lenders offer only one product, borrowers make only the discrete product choice, then equation (12) collapses to the standard mark-up pricing formula with one price: $r_{jt}^{*} = mc_{jt} - \frac{\sum_i s_{ijt}}{\sum_i \frac{\partial s_{ijt}}{\partial r_{jt}}}$.

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

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

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

$$\frac{f_{jt}^{*}}{\tau_{jt}} = \overbrace{\frac{a_{jt}}{\tau_{jt}}}^{\text{Application cost}} - \frac{\overbrace{\sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}}}^{\text{Mark-up}}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}} - \frac{\overbrace{\sum_m \sum_i \left(s_{ijmt} \frac{\partial q_{ijmt}}{\partial f_{jt}} + q_{ijmt} \frac{\partial s_{ijmt}}{\partial f_{jt}} \right)}^{\text{Net Interest Income}}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}} (r_{jt}^{*} - mc_{jt})$$
$$\underbrace{- \frac{\sum_m \sum_{k \neq j \in J_{lmt}} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left(\frac{f_{kt}^{*} - a_{kt}}{\tau_k} + q_{ikmt}(r_{kt}^{*} - mc_{kt}) \right)}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}}}_{\text{Other products}}. \tag{14}$$

Equations (12) 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

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

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

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 that arise from unobservable product characteristics.

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 the product fixed effect

$$\delta_{jmt} = \log(\mu_m) - \alpha_m \log(r_{jt}) + \beta_m X_j + \xi_{jmt} \tag{17}$$

captures all observed and unobserved attributes of product j in market m and quarter t, and φ_{mt} is a market-period fixed effect that captures the relative benefit of renting versus buying a property in market m.

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, with two nests: (1) an inside nest with all mortgage products $j \in J_i$ in market m and quarter t for those who choose to buy a property and take out a mortgage; and (2) an outside nest with the choice of renting a property $j = 0$.

Hence, the probability $s_{ijmt|j\in J_i}(\zeta_i)$ that household i with unobserved heterogeneity ζ_i chooses mortgage product j in his choice set J_i, conditional on taking out a mortgage in

market m and quarter t, 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 rents a property, and thus does not take out any mortgage product 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 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 mortgage, in each of the 20 markets we defined

in Section 3 as a combination of 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 characteristics, 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 ξ_{jmt}.

This first step yields estimates of the following parameters:

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

In the second step, we estimate the binary logit probability (19) using Bank of England Household Survey data to obtain the nesting parameter ρ_m and the market-quarter fixed effects φ_{mt} that enter the indirect utility of renting (16). 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 demographics (income and age). Because the survey has few observations, we pool all households from different markets and 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 local branch network enters into the discrete choice only. Specifically, we exploit variation in the branch network, along with variation on the location of borrowers' houses at the postcode level, to identify the effect of lenders' local branch networks on borrowers' choice of lenders.

Second, lenders simultaneously set interest rates and origination fees, which could be

correlated with unobserved product characteristics. For example, a lender could raise the interest rate and 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 choice depend on the lender's unobserved characteristics.

Our estimation procedure addresses the possible correlation between fees f_{jt} and unobservable characteristic 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 that 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 that is correlated with $Y_i - f_{jt}$ identifies the parameter γ_m in the discrete-choice equation.

Moreover, our estimation deals with the possible correlation between interest rate r_{jt} and unobservable characteristic ξ_{jmt} in regression (17) by exploiting two cost shifters of the interest rate previously employed and motivated in Benetton (2020) and Robles-Garcia (2020): (1) risk-weighted capital requirements. These capital requirements affect lenders' cost of supplying a specific product, and they vary across products and across lenders, depending on whether they use an internal model or a standardized approach to measure credit risk. (2) Euro interest-rate swaps for 2, 3, and 5 years. Swap rates are a hedging instrument lenders use when selling mortgages with fixed periods of 2, 3, and 5 years, respectively; thus, they vary across time and across products. Our exclusion restriction is that once we control for lender and market fixed effects, these two instruments do not affect borrowers' choice directly, but they do indirectly through their effects on mortgage rates only.

5.2 Supply

Estimation. Estimation of the supply-side parameters relies on lenders' optimal pricing. We recover the marginal cost mc_{jt} and the application costs a_{jt} of each product j by solving equations (12) and (14). This is a routine procedure in most equilibrium structural IO models, because the number of first-order conditions equal the number of unknown marginal costs, and thus the system of equations is exactly identified. In our case, recovering costs faces a few challenges. First, many mortgage products with identical non-price characteristics display multiple rate-fee quotes, as Figure 2 shows. We think it is plausible that these different products with identical non-price characteristics have the same marginal costs mc_{jt} and application costs a_{jt}. Hence, if we impose that these products have the same costs and use all first-order conditions, the system of equations is over-identified.

Second, some products have zero fees and we think it is not plausible that the first-order conditions (14) for the optimal fees hold with equality in these cases. We could choose not to include these first-order conditions in our system of equations, because our previous argument implies that the system is over-identified, but of course this exclusion would entail an efficiency loss.

We choose 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 adds one unknown auxiliary parameter ν_{jt} for each zero-fee first-order condition, thereby allowing us to exploit all of the first-order conditions to recover marginal costs mc_{jt} and application costs a_{jt}, while keeping the number of over-identifying restrictions unchanged. In practice, we let marginal costs mc_{jt} vary with all non-price characteristics and impose the same marginal cost for all products with multiple rate-fee quotes in the same t.[10] We further impose the same application costs a_{jt} for all products within each lender and LTV band for each t.

Having recovered marginal costs mc_{jt}, we let the components c^o_{jt} and c^f_{lt} be flexible functions of observed and unobserved characteristics of mortgage product j and lender l, respectively. We also allow lenders' funding costs to depend on their drawings of FLS funds in a parsimonious way, consistent with our approach in Section 4.2 as set forth in equation (9).

[10] In principle, we could allow products with the same non-price characteristics but multiple rate-fee quotes to have different costs and tests for equality.

More precisely, we specify costs as follows:

$$c^o_{jt} = \omega^o_l + \omega^o_t + \omega^o_X X_j + \kappa^o_{jt}, \tag{24}$$

$$c^f_{lt} = \omega^f_l + \omega^f_t + \omega^f_X X_{lt} + \omega^f \mathbb{1}\{Q^F_{lt} > 0\} + \kappa^f_{lt}, \tag{25}$$

where ω^o_l and ω^f_l are lender fixed effects; ω^o_t and ω^f_t are quarter fixed effects; X_j are product characteristics; X_{lt} are lender characteristics; $\mathbb{1}\{Q^F_{lt} > 0\}$ is an indicator variable equal to one when lender l uses FLS funds in quarter t (described more precisely below); and κ^c_{jt} and κ^f_{lt} are structural error terms capturing unobservable time-varying determinants of costs.

Combining costs (24) and (25), we then estimate the following regression:

$$mc_{jt} = \omega^c_l + \omega^c_t + \omega^f \mathbb{1}\{Q^F_{lt} > 0\} + \omega^o_X X_j + \omega^f_X X_{lt} + \kappa_{jt}, \tag{26}$$

where mc_{jt} is the estimated marginal cost; $\omega^c_l = \omega^o_l + \omega^f_l$ are lender fixed effects; $\omega^c_t = \omega^o_t + \omega^f_t$ are quarter fixed effects; and $\kappa_{jt} = \kappa^c_{jt} + \kappa^f_{lt}$ is the combined structural error term capturing unobservable time-varying determinants of marginal costs.

We use two related definitions of the indicator variable $\mathbb{1}\{Q^F_{lt} > 0\}$: The first one is whether lender l has a net positive drawing flow on FLS funds in quarter t; the second is whether lender l has a net positive drawing stock on FLS funds in quarter t. 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 indicator variable $\mathbb{1}\{Q^F_{lt} > 0\}$ is endogenous. Thus, we estimate equation (25) by exploiting instruments we now describe.

Identification. The main parameter of interest in cost equation (26) is the coefficient ω^f of the indicator variable $\mathbb{1}\{Q^F_{lt} > 0\}$, 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 U.K. lenders (Churm, Joyce, Kapetanios, and Theodoridis, 2021)—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

potentially unobservable, time-varying lender cost components κ_{lt}^f. Hence, we implement an instrumental variable approach that exploits the demand-side institutional features of the U.K mortgage market described in Section 3; specifically, the fact that mortgage products feature a relatively short fixation period—in the most typical case, 2 years, after which most borrowers refinance (Cloyne, Huber, Ilzetzki, and Kleven, 2019; Belgibayeva, Bono, Bracke, Cocco, and Majer, 2020). Hence, the volume of mortgages lenders originated approximately 2 years prior should affect lenders' expectation of their demand for internal refinancing, and thus their need for new funds, because of, for example, cash-out refinancing and changes in house prices and/or income.[11] Thus, a higher expected demand for refinancing should affect lenders' decisions to access FLS facilities—i.e., whether to draw in a given quarter, and how much to draw—but it should be plausibly uncorrelated with the unobservable components of their marginal costs in a given quarter. Moreover, this expected demand for remortgaging depends on banks' past mortgage lending, which is clearly predetermined when the FLS program was announced.

In practice, we implement this idea using the following instruments for $\mathbb{1}\{Q_{lt}^F > 0\}$: (1) the value of residential mortgages issued by lender l in quarter $t-9$;[12] (2) the number of residential mortgages issued by lender l in quarter $t-9$; (3) a lender-specific growth rate in house prices, constructed as the weighted average of the growth rate of house prices in each three-digit postcode weighted by the number of branches of lender l in each postcode; and (4) a lender-specific growth rate in household income, constructed as the weighted average of the growth rate of household income in each three-digit postcode weighted by the number of branches of lender l in each postcode.

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.

[11] Changes in house prices or income may also affect first-time buyers and home-movers' choices, thereby strengthening the case that they are suitable demand-side instruments.

[12] Using a lag of eight quarters in the construction of the instruments yields estimates of the same sign as those reported in Table 6, though approximately 100 bps lower.

Table 4: Demand Parameters

	α	$\beta_{HighLTV}$	β_{Fix5}	$\tilde{\lambda}$	ψ	$\tilde{\gamma}$	σ	ρ
Mean	0.26	0.09	0.03	0.02	0.21	0.02	0.34	0.02
Standard Deviation	0.09	0.03	0.01	0.00	0.15	0.00	0.02	0.00

Notes: The table reports the mean and standard deviation of estimated demand parameters in the population.

6.1 Demand Parameters

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 confidence intervals of the demand parameters in each group.

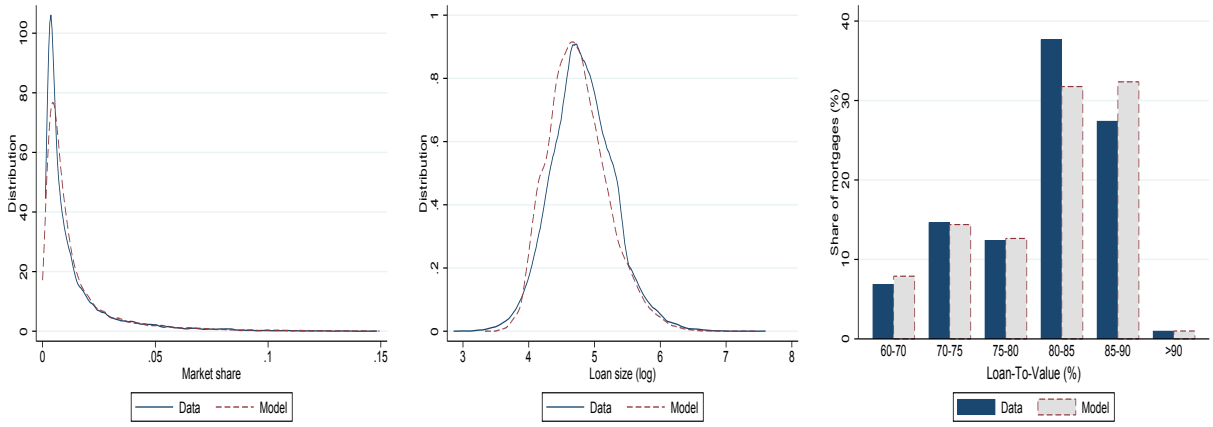
The sign of these parameters is largely as expected, and their magnitudes and heterogeneity are often noteworthy. Specifically, the parameter α, which measures the sensitivity to interest rates, displays substantial heterogeneity across individuals. Parameters $\beta_{HighLTV}$ and β_{Fix5} indicate that borrowers prefer mortgages with higher maximum LTV limits and fixed-rate mortgages with longer fixation periods, respectively. The parameter $\tilde{\lambda}$ indicates that a higher density of branches in a location has a positive effect on borrowers' product demand, though this coefficient is quite small. The parameter ψ indicates a departure from quasi-linearity in income, with substantial heterogeneity in our population. The parameter σ implies that unobserved heterogeneity plays a moderate role in the mortgage market. Finally, the parameter ρ indicates a small substitution between buying a house and renting.

Figure 6 displays several plots that illustrate how the model fits the data. Overall, the fit is good, indicating that the model captures the heterogeneity of the data well, 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.

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 origination fee. Panel A reports the elasticities of the expected demand $\sum_m \sum_{i \in I_{mt}} s_{ijmt} q_{ijmt}$, which combines the continuous loan demand (Panel B) and the discrete product demand (Panel C), respectively.

Panel A shows that, on average, borrowers are substantially more elastic to the interest rate than the origination fee. However, elasticity with respect to the fee exhibits a larger coefficient of variation than elasticity with respect to the interest rate. Panel B reports that,

Figure 6: 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).

Table 5: Demand Elasticities to Rates and Fees

	Mean	Sd	p10	Median	p90
Panel A: Total Demand					
Elasticity Rate	-9.04	0.92	-10.14	-9.10	-7.87
Elasticity Fee	-0.49	0.74	-1.13	-0.17	-0.00
Rate decrease per £1,000 Fee	-0.24	0.21	-0.51	-0.16	-0.05
Panel B: Continuous Demand					
Elasticity Rate	-1.26	0.04	-1.32	-1.26	-1.21
Elasticity Fee	-0.48	0.73	-1.11	-0.16	-0.00
Rate decrease per £1,000 Fee	-1.51	1.39	-3.27	-0.97	-0.26
Panel C: Discrete Demand					
Elasticity Rate	-7.78	0.90	-8.82	-7.83	-6.65
Elasticity Fee	-0.01	0.01	-0.02	-0.01	-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 $\sum_m \sum_{i \in I_{mt}} s_{ijmt} q_{ijmt}$ 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.

on average, a one percent increase in the interest rate leads to a 1.26 percent decrease in the loan size. Panel C reports that, on average, a one percent increase in the rate leads to a 7.78 percent decrease in market share, which is slightly higher than previous studies of U.K. and U.S. mortgage markets (Benetton, 2020; Buchak, Matvos, Piskorski, and Seru, 2020). Hence, the product demand exhibits substantially higher elasticity to the interest rate than the continuous demand, whereas the two panels show that the elasticities with respect to the fee are broadly similar. These magnitudes seem to suggest that borrowers may be shopping across lenders and across products for a low interest rate without focusing much on the origination fee.

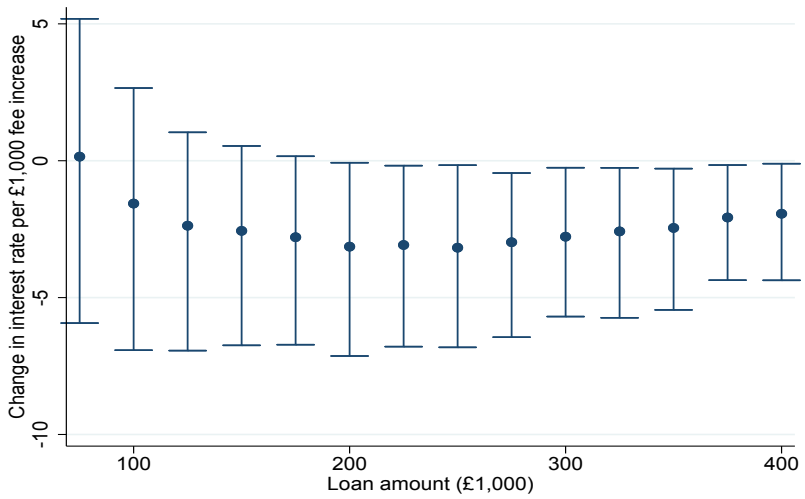
To gain a better sense of the relative magnitudes of these different demand elasticities with respect to rates and fees, we calculate the decrease in interest rates that fully offsets a £1,000 increase in the origination fee in borrowers' demand functions. The last row of Panel A reports this magnitude for the expected total demand $\sum_m \sum_{i \in I_{mt}} s_{ijmt} q_{ijmt}$. Overall, such an increase requires an average decrease of 24 bps, with considerable heterogeneity across mortgage products—the 10th percentile equals 51 bps, the median equals 16 bps, and the 90th percentile equals 5 bps. Hence, the average magnitude is quite close to that of the empirical "exchange rate" between 27 bps and £1,000 in fees that we reported in Table 2, though slightly lower, which corroborates that borrowers on average seem to 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 rate 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 seem substantially larger than those that cost-minimization arguments imply. To appreciate some of this heterogeneity, 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 $d\left(\frac{f_{jt}}{\tau_{jt}}\right)$:

$$dr_{jt} = -\frac{\left(1 + r_{jt} \frac{\partial q_{ijmt}}{\partial \left(\frac{f_{jt}}{\tau_{jt}}\right)}\right)}{\left(q_{ijmt} + r_{jt} \frac{\partial q_{ijmt}}{\partial r_{jt}}\right)} d\left(\frac{f_{jt}}{\tau_{jt}}\right), \tag{27}$$

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 7: Change in Interest Rates



Notes: This figure displays the basis-point change in interest rate calculated as in equation (27) 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 average within each bin and the vertical whiskers correspond to the range of 90th-10th percentiles within each bin.

Figure 7 displays the bps change in the interest rate calculated as in equation (27) 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.[13] The figure shows that the large heterogeneity across borrowers is at odds with pure cost-minimization arguments for two main reasons. First, the average change in interest rates (the dot marker) is almost flat across the different bins of loan amounts, increasing only for large loans. However, cost-minimization arguments imply that the change in the average 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 90th-10th 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 90th-10th 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 90th-10th 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.

[13] Changes in annualized fees and interest rates as in equation (27) would likely lead borrowers to choose a different mortgage product. Hence, Figure 7 focuses exclusively on the changes due to the loan demand (22).

6.2 Supply Parameters

Table 6 collects coefficient estimates of equation (26). The dependent variable is the estimated marginal cost 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' marginal costs. In the regressions reported in columns (1)-(5), $\mathbb{1}\{Q_{lt}^F > 0\}$ equals the net positive drawing flow on FLS funds in quarter t, whereas in those reported in columns (6)-(10) it equals the net positive drawing stock on FLS funds in quarter t. All regressions further include mortgage product characteristics and lender characteristics, obtained from their balance sheets, as well as quarter and lender fixed effects.

Columns (1) and (6) present OLS estimates. Both coefficients are positive, though not significantly different from zero, which suggests that FLS funds have a small positive or no effect on lenders' marginal costs. 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 coefficients in columns (1) and (6) are upward biased.

Columns (2) and (7) report the first-stage estimates of our IV regressions. They show that our instruments, based on the idea that lenders may access FLS funds based on their expected internal refinancing activity, have a strong positive correlation with the decision to borrow from FLS facilities in quarter t. We should point out that columns (2) and (7) show that several bank controls do not seem to play a significant role in the first stage, with the exception of the capital ratio, which suggests that worse-capitalized banks are more likely to use FLS facilities.

Columns (3) and (8) report second-stage IV estimates. They indicate that borrowing from FLS facilities reduced lenders' funding costs by approximately 70-72 bps. This magnitude is remarkably similar across the two definitions of lenders' use of FLS facilities. Moreover, this magnitude of approximately 70 bps 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 U.K. lenders. Given an average marginal cost of approximately 350 bps in the quarters before introduction of the FLS, the FLS decreases marginal costs by approximately 20 percent.

While our main focus is on the effects of the FLS, Table 6 also reports estimates for other variables that affect the marginal cost of offering a mortgage. Higher risk weights increase

Table 6: The FLS and Marginal Costs

	FLS Flow					FLS Stock				
	(1) OLS	(2) FS	(3) IV	(4) FS	(5) IV	(6) OLS	(7) FS	(8) IV	(9) FS	(10) IV
FLS										
Drawing flow > 0	0.038		-0.734**		-0.622**					
	(0.066)		(0.313)		(0.279)					
Cumulative drawing flow > 0						0.039		-0.705**		-0.720**
						(0.111)		(0.346)		(0.351)
Supply shifters										
Risk weights	4.028**	-0.364***	3.890**	-0.375***	3.910**	4.004**	0.347**	4.317***	0.338**	4.323***
	(1.551)	(0.121)	(1.568)	(0.121)	(1.568)	(1.559)	(0.142)	(1.589)	(0.141)	(1.587)
Swap rates	0.357*	-0.047	0.276	-0.046	0.288	0.357*	-0.064	0.276	-0.066	0.275
	(0.193)	(0.048)	(0.204)	(0.047)	(0.204)	(0.192)	(0.047)	(0.201)	(0.046)	(0.202)
Mortgage characteristics										
High LTV	0.673***	0.030***	0.688***	0.030***	0.686***	0.675***	-0.017	0.659***	-0.017	0.659***
	(0.151)	(0.011)	(0.152)	(0.011)	(0.152)	(0.152)	(0.013)	(0.154)	(0.013)	(0.154)
Variable rate	-0.193*	-0.002	-0.199*	-0.002	-0.198*	-0.193*	0.000	-0.195*	-0.000	-0.195*
	(0.102)	(0.014)	(0.102)	(0.014)	(0.102)	(0.102)	(0.010)	(0.101)	(0.010)	(0.102)
Fix 5 years	0.294**	0.034	0.343**	0.034	0.336**	0.294**	0.044*	0.344**	0.046*	0.344**
	(0.140)	(0.024)	(0.146)	(0.024)	(0.144)	(0.139)	(0.026)	(0.144)	(0.025)	(0.143)
Bank characteristics										
Sight deposits	-3.668***	-0.443	-2.379*	-0.704	-2.566*	-3.688***	0.914	-2.092	0.728	-2.062
	(1.389)	(0.511)	(1.397)	(0.520)	(1.381)	(1.374)	(0.596)	(1.726)	(0.623)	(1.725)
Time deposits	-4.096**	0.134	-4.038**	0.088	-4.046**	-4.127**	0.670	-3.499*	0.632	-3.487*
	(1.670)	(0.802)	(1.811)	(0.816)	(1.777)	(1.677)	(0.922)	(1.768)	(0.938)	(1.778)
Capital ratio	7.839**	-2.414**	4.182	-2.410**	4.711	7.844**	-3.270***	4.336	-3.206***	4.269
	(3.489)	(1.029)	(3.620)	(1.051)	(3.678)	(3.455)	(1.119)	(3.576)	(1.131)	(3.690)
Assets	3.036***	0.060	3.089***	0.032	3.081***	3.086***	-1.118***	2.180***	-1.114***	2.163**
	(0.743)	(0.206)	(0.751)	(0.209)	(0.746)	(0.793)	(0.241)	(0.777)	(0.244)	(0.829)
Excluded instruments										
Past Mortgages (number)		-1.730***		-1.815***			-1.255***		-1.338***	
		(0.282)		(0.283)			(0.287)		(0.282)	
Past Mortgages (£)		1.629***		1.720***			1.073***		1.157***	
		(0.262)		(0.262)			(0.270)		(0.265)	
Net income (change log)		-9.936***					-7.314***			
		(1.953)					(1.430)			
Property value (change log)		7.094***					4.644***			
		(1.807)					(1.120)			
PTI (change log)				10.105***					3.793***	
				(2.139)					(1.242)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal cost (mean)	3.21	0.21	3.21	0.21	3.21	3.21	0.43	3.21	0.43	3.21
F statistic			13.42		17.34			11.74		10.33
Adjusted R^2	0.56	0.56	0.52	0.56	0.53	0.56	0.85	0.54	0.85	0.54
Observations	1,097	1,097	1,097	1,097	1,097	1,097	1,097	1,097	1,097	1,097

Notes: The dependent variable is the marginal cost of lending. Standard errors are clustered at the product level.

marginal costs, as they raise the capital that lenders need in order to increase mortgage lending. Similarly, higher swap rates increase marginal costs, since they increase the spread lenders have to pay to exchange the fixed interest rate for the variable benchmark, though these coefficients are not precisely estimated. Mortgage products with greater default risk, measured by a higher LTV, have higher marginal costs, as expected. Moreover, we find that mortgages with a a longer fixed rate, which carry greater interest rate risk for lenders, have higher marginal costs and mortgages with variable rates have lower marginal costs than those with a short-term fixed rate (the baseline category).

Columns (4)-(5) and (9)-(10) present first- and second-stage regressions that combine the instruments in a slightly different way. The second-stage estimates in columns (5) and (10) are almost identical to the main ones in columns (3) and (7).

In Appendix E, we report on two additional set of regressions: (1) Table E1 performs regressions similar to those displayed in Table 6 using the estimated application cost a_{ij} as dependent variable. We do not find any evidence that the FLS program affected application costs, which provides a useful placebo test of our analysis, since changes in funding costs should be orthogonal to any changes in lenders' costs of processing mortgage applications. (2) Table E2 presents further results that use continuous measures of FLS drawings, rather than the indicator variables $\mathbb{1}\{Q_{lt}^F > 0\}$ used in Table 6. The point estimates confirm that larger FLS drawings lowered lenders' funding costs more, though some estimates are noisier than those reported in Table 6.[14]

7 Model Implications and Counterfactual Policies

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

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

[14]It is quite plausible that FLS drawings had slightly different intensive vs. extensive margin effects on lenders' costs.

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

	Pre-FLS (2011Q3)	FLS data (2013Q3)		FLS model	
	Level	Level	Percent Change	Level	Percent Change
	(1)	(2)	(3)	(4)	(5)
Costs:					
Marginal Costs (bps)	315	273	-13.32	258	-18.25
	(115)	(83)		(112)	
Application Costs (£)	3,691	3,210	-13.03	3,691	0.00
	(3,627)	(3,957)		(3,627)	
Prices:					
Interest Rates (bps)	454	383	-15.73	415	-8.64
	(120)	(117)		(141)	
Origination Fees (£)	862	988	+14.70	1,003	+16.38
	(1,271)	(1,115)		(1,279)	
Number of Products	106	125	+17.92	106	0.00
Quantities:					
Mortgage Debt (£)	1,071,464	1,413,351	+31.91	1,438,318	+34.24
Loan Amount (£)	124,744	134,782	+8.05	163,076	+30.73
	(63,380)	(71,646)		(87,989)	
Number of Mortgages	7,417	8,971	+20.95	7,608	+2.57

Notes: Columns (1) and (2) report market 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 market outcomes of a counterfactual market based on 2011Q3, in which we exclusively reduce the costs of those lenders with a net positive stock of FLS drawings in 2013Q3 by 70 bps. Standard deviations in parentheses. Column (5) reports the percent change between column (4) and column (1).

parameters in the two quarters. The top part of Table 7 reports the averages and standard deviations (in parentheses) of marginal costs and application costs. These statistics place equal weight on each mortgage product. Comparison between the pre-FLS period and post-FLS period reveals that lenders' average costs declined: marginal costs by 42 bps and application costs by £481.

The middle part reports lenders' posted average interest rates and origination fees (again, these statistics weight each mortgage product equally). It indicates that lenders lower their interest rates on average by 71 bps, but they increase their origination fees on average by £126. Moreover, the middle part of the table reports that the number of mortgage products also increases from 106 in the pre-FLS market to 125 in the FLS market.

The bottom part of Table 7 reports statistics on mortgage demand, decomposing it between the intensive (average loan amount) and extensive margin (number of mortgages). Aggregate mortgage debt increased by approximately 32 percent from 2011Q3 to 2013Q3, with the average mortgage amount increasing by approximately £10,000, or 9 percent of the

2011Q3 average loan amount, and the number of mortgages increasing by approximately 1,500, or 21 percent of 2011Q3 originations.

While 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 application costs declined £3,691 to £3,210 and that the number of mortgage products offered increased from 106 to 125, whereas our model does not consider the reasons for these changes. Hence, we aim to isolate the effect of the FLS on market outcomes by performing a cleaner, more controlled comparison between the market in 2011Q3 and a counterfactual market in which the FLS exclusively affects lenders' funding costs. Specifically, based on the cost estimates of Table 6, we reduce the marginal costs of those lenders with a net positive stock of drawings on FLS funds—i.e., $\mathbb{1}\{Q_{lt}^F > 0\}$ in columns (6)-(10) of Table 6—by 70 bps. We keep application costs, the number of mortgage products, as well as borrower characteristics, constant to their 2011Q3 sample values.

Column (4) reports the market outcomes of this case. The top part confirms that FLS facilties reduced lenders' marginal costs, on average by 57 bps (because some lenders had a zero net positive stock of FLS drawings at 2011Q3, the reduction in average marginal costs is lower than 70 bps). However, the middle part of the table shows that lenders did not fully pass this cost reduction through to borrowers, because on average they decreased interest rates by only 39 bps, implying a pass-through of $39/57 = 0.68$. Moreover, they increased origination fees by £141 even though their application 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, previously displayed in Figure 3.

As a result of these price changes, aggregate mortgage debt increases by approximately 34 percent, which is almost identical to the increase observed in the data. The model predicts that borrowers' average loan size increases by approximately £38,000, or 30 percent of the 2011Q3 average loan amount, and the number of mortgages increases by approximately 190, or 2.6 percent of 2011Q3 originations. Hence, the model implies a 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) changes in lenders' products, as well as borrower demographic characteristics, between 2011Q3 and 2013Q3 that we are instead keeping fixed in this analysis; and (2) perhaps 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.

Heterogeneity across Groups. Table 8 focuses on the heterogeneity of the effects of the FLS across borrower groups. 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 a net positive stock of FLS drawings are 70 bps lower, as in column (4) of Table 7. Columns (9) and (10) report the percent change in consumer surplus and lender profits between the counterfactual and the baseline markets.

This table reveals interesting findings. First, the comparisons between the average posted prices—454 bps and £862 in the pre-FLS market in column (1), 415 bps and £1,003 in the FLS model market in column (4)—reported in Table 7 and the average prices paid—420 bps and £1,043 in the pre-FLS market in columns (1) and (2), 342 bps and £1,373 in the FLS market in columns (5) and (6)—reported at the top of Table 8 confirm that borrowers 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 all borrower groups pay lower interest rates, but higher fees, in the FLS market.

Second, Table 8 reports that the FLS increases aggregate welfare, and consumers and lenders share the gains: Consumers surplus increases by 2.90 percent and lender profits increase by 20.99 percent (Appendix D reports the formulas used to compute consumer surplus). Moreover, households in areas with higher house prices, and thus higher loan sizes—such as London and Southern England—tend to enjoy the largest gains in consumer surplus. The reason is that the decrease in interest rates due to the FLS favors areas in which borrowers have larger loans because of higher house prices. Nevertheless, within those areas, many groups of low-income households sustain large increases in consumer surplus. This is because low-income households exhibit a larger sensitivity to interest rates; thus, they experience large welfare gains amid the decline in interest rates, conditional on their loan size.

Table 8: Effects of the FLS on Borrower Groups

Region	Age	Income	Pre-FLS (2011Q3) Rate	Fee	Loan Amount	Number of Mortgages	FLS model Rate	Fee	Loan Amount	Number of Mortgages	Percent Change Consumer Surplus	Lender Profits
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Aggregate			420	1,043	124,744	7417	342	1,373	163,076	7608	2.90	20.99
			(59)	(122)	(63,380)		(56)	(219)	(87,989)			
London	Young	Low	383	1,093	154,177	310	302	1,481	211,972	324	4.78	7.26
			(51)	(110)	(59,935)		(47)	(76)	(88,098)			
London	Young	High	401	923	231,638	324	323	1,279	279,538	335	3.96	0.38
			(54)	(86)	(96,131)		(46)	(117)	(122,376)			
London	Old	Low	380	1,031	170,121	200	295	1,422	238,806	209	4.95	1.97
			(47)	(107)	(65,495)		(45)	(102)	(98,959)			
London	Old	High	385	840	272,262	247	305	1,176	375,615	252	11.28	14.11
			(60)	(105)	(132,874)		(68)	(91)	(223,158)			
Southern England	Young	Low	420	1,084	130,525	439	341	1,433	173,735	457	3.99	17.89
			(58)	(84)	(46,038)		(47)	(91)	(61,390)			
Southern England	Young	High	418	965	177,546	463	340	1,161	231,884	477	3.35	26.85
			(58)	(80)	(66,187)		(62)	(172)	(102,978)			
Southern England	Old	Low	380	978	134,569	393	315	1,266	171,177	405	3.38	20.70
			(50)	(96)	(49,601)		(40)	(103)	(63,265)			
Southern England	Old	High	414	885	192,943	483	341	1,259	236,741	491	2.51	17.14
			(55)	(94)	(76,891)		(50)	(206)	(102,385)			
Central England	Young	Low	433	1,096	102,278	467	356	1,602	129,659	480	3.08	27.17
			(58)	(92)	(37,222)		(44)	(88)	(47,559)			
Central England	Young	High	441	919	126,379	243	361	1,421	161,212	250	3.39	20.69
			(53)	(96)	(42,317)		(43)	(309)	(53,184)			
Central England	Old	Low	407	1,045	102,424	325	335	1,420	128,713	332	2.63	21.67
			(50)	(100)	(37,098)		(41)	(134)	(46,784)			
Central England	Old	High	441	884	139,515	331	359	1,168	185,295	333	1.58	22.42
			(55)	(75)	(62,882)		(56)	(242)	(109,748)			
Northern England	Young	Low	445	1,068	85,442	605	369	1,437	108,005	620	2.49	38.79
			(61)	(96)	(32,837)		(49)	(169)	(42,157)			
Northern England	Young	High	432	1,022	120,158	503	362	1,314	145,139	515	2.66	35.61
			(62)	(134)	(43,765)		(49)	(123)	(55,042)			
Northern England	Old	Low	415	1,064	91,707	451	347	1,389	113,175	459	2.15	29.99
			(61)	(96)	(35,925)		(50)	(101)	(44,052)			
Northern England	Old	High	420	943	125,382	474	346	1,350	150,784	480	2.18	16.80
			(60)	(110)	(55,174)		(51)	(76)	(68,811)			
Wales and Scotland	Young	Low	432	1,128	86,257	407	362	1,394	106,972	416	2.48	31.35
			(52)	(110)	(33,815)		(41)	(76)	(43,128)			
Wales and Scotland	Young	High	424	889	126,387	260	348	1,125	156,910	265	2.79	25.59
			(56)	(104)	(50,876)		(44)	(165)	(62,399)			
Wales and Scotland	Old	Low	407	1,043	86,880	253	241	819	190,506	266	5.73	40.31
			(41)	(113)	(33,776)		(80)	(418)	(108,763)			
Wales and Scotland	Old	High	431	981	128,949	239	345	1,325	172,024	242	2.01	11.70
			(54)	(107)	(55,956)		(59)	(283)	(96,323)			

Notes: Columns (1)-(4) and (5)-(8) report mortgage market outcomes for different groups of households in the estimated model in 2011Q3 and in a counterfactual market in which we exclusively reduce the costs of those lenders with a net positive stock of FLS drawings in 2013Q3 by 70 bps, respectively. Columns (9) and (10) report the percent change in consumer surplus and lender profits between the two markets.

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, and 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.[15] Our estimated model seems well suited to yield insights into how such regulation could affect market outcomes.

Table 9 compares outcomes under the 2011Q3 baseline market with a counterfactual market in which regulation does not allow lenders to charge origination fees. Of course, marginal costs and application costs do not change between the baseline case and the counterfactual case. As a result of a constraint on fees, lenders increase the interest rates they charge on their mortgages. Table 9 reports that interest rates would increase by 141 bps as a result of the forced decrease in origination fees.

As a result of the changes in lender posted prices, aggregate mortgage debt declines by approximately 9.5 percent. The average loan size increases by slightly more than £10,000, or 8.8 percent of the 2011Q3 average amount, whereas the number of mortgages originated declines by approximately 160 units, or 2 percent.

Heterogeneity across Groups. Table 10 reports on the heterogeneity of the effect of fees across borrower groups, with some interesting findings. First, the increase in interest rates paid by borrowers (from 420 to 482 bps) is smaller than the increase in interest rates posted by lenders (from 454 to 595 bps) reported in Table 9. This indicates that borrowers they choose mortgage products with lower LTV, which have a lower interest rates than higher LTV products, and thus decrease their leverage. The table indicates that this decrease in leverage is broadly uniform across borrower groups.

Second, in aggregate, banning fees decreases aggregate welfare, which harms both borrowers and lenders. Consumer surplus decreases by 2.43 percent and lender profits by 3.45 percent. Moreover, all household groups suffer a decrease in consumer surplus as interest rates increase. Nevertheless, households in areas with higher house prices and, thus, higher loan sizes—such as London and Southern England—suffer the largest decrease in consumer

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

Table 9: The Effects of Banning Fees on Mortgage Supply and Demand

	Pre-FLS (2011Q3)	No Fees	
	Level	Level	Percent Change
	(1)	(2)	(3)
Costs:			
Marginal Costs (bps)	315	315	0.00
	(115)	(115)	
Application Costs (£)	3,691	3,691	0.00
	(3,627)	(3,627)	
Prices:			
Interest Rates (bps)	454	595	+30.91
	(120)	(129)	
Origination Fees (£)	862	0	-100.00
	(1,271)	(0)	
Number of Products	106	106	0.00
Quantities:			
Mortgage Debt (£)	1,071,464	970,225	-9.45
Loan Amount (£)	124,744	113,778	-8.79
	(63,380)	(59,658)	
Number of Mortgages	7,417	7,256	-2.17

Notes: Column (1) reports market outcomes for the estimated model in 2011Q3. Column (2) reports market outcomes of a counterfactual market based on 2011Q3 in which lenders cannot charge origination fees. Column (3) reports the percent change between columns (2) and (1). Standard deviations in parentheses.

surplus. The reason is that the interest-rate changes impose a heavier burden on borrowers with larger mortgage loans. Lender profits tend to increase in areas with higher house prices, because interest margins increase, and interest income accounts for a larger share of profits, most notably for higher-income borrowers with larger mortgage loans. Similarly, lender profits decrease in areas with lower house prices, and in particular for borrowers with the lowest loan sizes, because fee income accounts for a larger share of profits for those groups.

8 Conclusion

This paper studies the effects of central bank policies on credit markets by studying the U.K. residential mortgage market around the introduction of the Bank of England's Funding for Lending Scheme. We provide novel descriptive evidence on how U.K. lenders use menus with two-part tariffs consisting of origination fees and interest rates to segment the market and price discriminate among heterogeneous households, and how central bank policies altered this pricing strategy.

The descriptive analysis motivates us to develop and estimate a structural demand-and-

Table 10: The Effects of Banning Fees on Household Groups

			Pre-FLS (2011Q3)				No Fees				Percent Change	
Region	Age	Income	Rate	Fee	Loan Amount	Number of Mortgages	Rate	Fee	Loan Amount	Number of Mortgages	Consumer Surplus	Lender Profits
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Aggregate			420	1,043	124,744	7417	482	0	113,778	7256	-2.43	-3.45
			(59)	(122)	(63,380)		(57)	(0)	(59,658)			
London	Young	Low	383	1,093	154,177	310	447	0	143,315	300	-3.44	-2.85
			(51)	(110)	(59,935)		(51)	(0)	(57,190)			
London	Young	High	401	923	231,638	324	461	0	228,592	315	-3.03	17.90
			(54)	(86)	(96,131)		(54)	(0)	(87,041)			
London	Old	Low	380	1,031	170,121	200	437	0	156,927	195	-3.23	4.26
			(47)	(107)	(65,495)		(44)	(0)	(61,753)			
London	Old	High	385	840	272,262	247	445	0	256,000	243	-2.32	21.70
			(60)	(105)	(132,874)		(57)	(0)	(114,871)			
Southern England	Young	Low	420	1,084	130,525	439	482	0	115,696	426	-3.06	-17.19
			(58)	(84)	(46,038)		(54)	(0)	(40,429)			
Southern England	Young	High	418	965	177,546	463	486	0	165,577	449	-3.14	7.74
			(58)	(80)	(66,187)		(57)	(0)	(58,842)			
Southern England	Old	Low	380	978	134,569	393	443	0	116,449	383	-2.74	-18.63
			(50)	(96)	(49,601)		(45)	(0)	(41,740)			
Southern England	Old	High	414	885	192,943	483	477	0	184,505	476	-2.09	16.66
			(55)	(94)	(76,891)		(57)	(0)	(69,322)			
Central England	Young	Low	433	1,096	102,278	467	485	0	92,243	456	-2.55	-26.89
			(58)	(92)	(37,222)		(52)	(0)	(33,205)			
Central England	Young	High	441	919	126,379	243	505	0	115,394	237	-2.66	-7.70
			(53)	(96)	(42,317)		(55)	(0)	(37,698)			
Central England	Old	Low	407	1,045	102,424	325	471	0	89,985	320	-2.21	-16.66
			(50)	(100)	(37,098)		(50)	(0)	(32,680)			
Central England	Old	High	441	884	139,515	331	509	0	130,658	329	-1.43	5.17
			(55)	(75)	(62,882)		(58)	(0)	(56,037)			
Northern England	Young	Low	445	1,068	85,442	605	508	0	75,834	591	-2.50	-21.78
			(61)	(96)	(32,837)		(53)	(0)	(29,227)			
Northern England	Young	High	432	1,022	120,158	503	490	0	114,212	491	-2.70	-7.03
			(62)	(134)	(43,765)		(59)	(0)	(40,661)			
Northern England	Old	Low	415	1,064	91,707	451	484	0	78,648	442	-2.21	-29.55
			(61)	(96)	(35,925)		(57)	(0)	(30,557)			
Northern England	Old	High	420	943	125,382	474	482	0	123,040	468	-1.99	-0.52
			(60)	(110)	(55,174)		(61)	(0)	(52,385)			
Wales and Scotland	Young	Low	432	1,128	86,257	407	500	0	75,923	396	-2.70	-21.19
			(52)	(110)	(33,815)		(52)	(0)	(30,392)			
Wales and Scotland	Young	High	424	889	126,387	260	461	0	122,380	254	-2.54	-8.79
			(56)	(104)	(50,876)		(51)	(0)	(49,633)			
Wales and Scotland	Old	Low	407	1,043	86,880	253	467	0	76,336	249	-2.11	-34.06
			(41)	(113)	(33,776)		(38)	(0)	(29,993)			
Wales and Scotland	Old	High	431	981	128,949	239	497	0	126,174	237	-1.73	-0.74
			(54)	(107)	(55,956)		(60)	(0)	(54,827)			

Notes: Columns (1)-(4) and (5)-(8) report mortgage market outcomes for different groups of households in the estimated model in 2011Q3 and in a counterfactual market in which lenders cannot charge origination fees, respectively. Columns (9) and (10) report the percent change in consumer surplus and lender profits between the two markets.

supply model of the U.K. mortgage market with rich household heterogeneity. We use the structural model to quantify the effects of the FLS on lenders' and borrowers' costs and mortgage lending, and to compute the welfare gains that accrued to households and lenders.

Our estimates indicate that the FLS program decreased participating lenders' costs by approximately 70 bps, which led them to decrease mortgage rates by approximately 40 bps but to increase origination fees by approximately £120, consistent with our descriptive evidence. Overall, mortgage lending increased, and both households and lenders benefited from the FLS program.

Moreover, our counterfactual analysis shows that origination fees allow lender to increase their profits. However, banning fees, thereby banning indirect price discrimination through two-part pricing, would lower borrower surplus and aggregate welfare.

Overall, a key contribution of our analysis is to emphasize that lenders' indirect price discrimination strategies represent a novel aspect that affects the transmission of central bank policies to heterogeneous households.

References

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., G. Amromin, S. Chomsisengphet, T. Landvoigt, T. Piskorski, A. Seru, and V. Yao (2020): "Mortgage Refinancing, Consumer Spending, and Competition: Evidence from the Home Affordable Refinancing Program," *Review of Economic Studies*, Forthcoming.

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 (2020): "Searching for Approval," Working Paper 27341, National Bureau of Economic Research.

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.

Bahaj, S., A. Foulis, G. Pinter, and P. Surico (2019): "Employment and the Collateral Channel of Monetary Policy," Bank of England working papers 827, Bank of England.

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. (2020): "Leverage Regulation and Market Structure: An Empirical Model of the UK Mortgage Market," *Journal of Finance*, Forthcoming.

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

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.

——— (2020): "Beyond the Balance Sheet Model of Banking: Implications for Bank Regulation and Monetary Policy," Working Paper 25419, National Bureau of Economic Research.

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

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.

Eaton, B. C., and R. G. Lipsey (1989): "Product Differentiation," in *Handbook of Industrial Organization*, ed. by R. Schmalensee, and R. Willig, vol. 1, pp. 723–768. Elsevier.

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

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

Greenwald, D. L., J. Krainer, and P. Paul (2020): "The Credit Line Channel," Working Paper Series 2020-26, Federal Reserve Bank of San Francisco.

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 (2021): "The cost of steering in financial markets: Evidence from the mortgage market," *Journal of Financial Economics*, Forthcoming.

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.

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

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.

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

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.

Robles-Garcia, C. (2020): "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.

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

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 some robustness checks on the pricing structure of U.K. mortgages using mortgage originations in the PSD. 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 our dataset for the structural 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 to 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; (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 (more than 300), and thus many have 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 124 product types and 186 products.

B The Funding For Lending Scheme

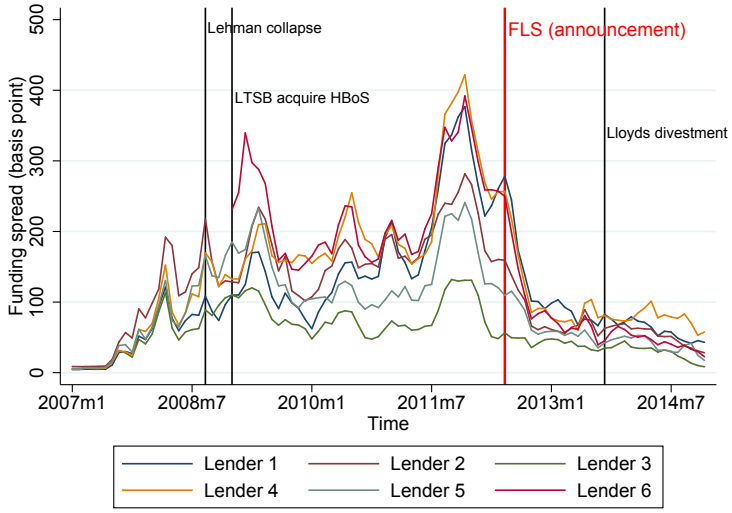
On June 14, 2012, the Governor of the Bank of England, Mervyn King, announced the introduction of the Bank of England and HM Treasury FLS program, which officially started on July 13, 2012. The scheme was part of the larger monetary stimulus package that the Bank of England had pursued since the onset of the financial crisis, along the lines of similar programs of other central banks (Borio and Zabai, 2016).[16]

The timing of the FLS followed an intensification of the European Sovereign Debt Crisis and an increase in banks' funding costs for major U.K. lenders, which in turn led to an increase in loan rates. Figure B1 displays funding spreads for the six (anonymized) largest U.K. lenders.[17] 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

[16]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 U.K. government securities, but also smaller quantities of high-quality corporate bonds.

[17]More formally, Figure B1 reports the constant maturity secondary market spreads to mid-swaps for the largest U.K. 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



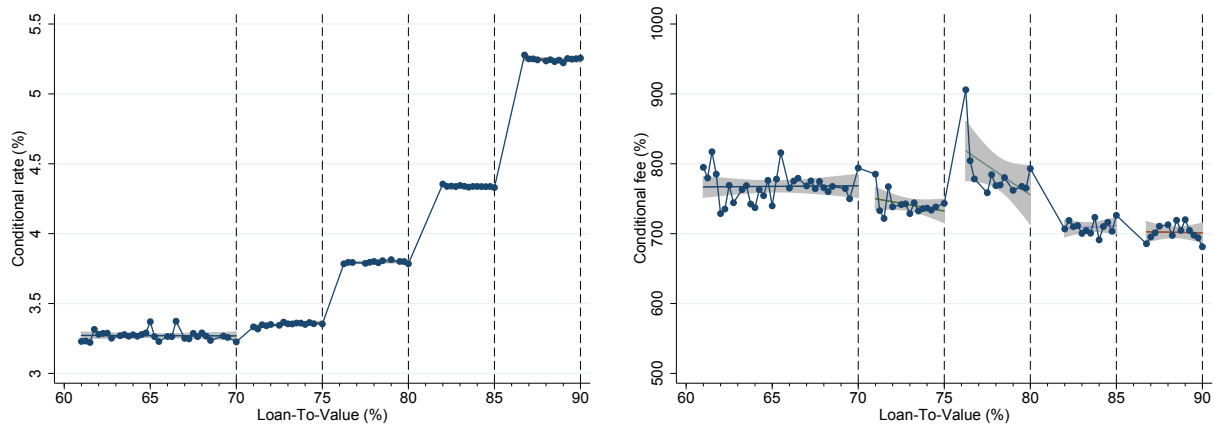
Notes: This figure displays the funding spreads of the six largest U.K. lenders.

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 at 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

Figure C1: LTV Pricing in the PSD



Notes: Panel (a) shows how average initial interest rates on 2010-2014 PSD mortgage originations vary within and across LTV bands. Panel (b) shows a similar picture for origination fees in the 2015 PSD, which is the first year when origination fees are available in the PSD.

£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, has 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.

C Mortgage Pricing in the PSD

Figure C1 illustrates the main pricing structure of U.K. mortgages using the PSD origination data. Specifically, the left panel shows that the residual interest rate (i.e., after controlling for mortgage characteristics) varies across LTV bands, with (almost) no variation within bands, consistent with the pattern reported by Cloyne, Huber, Ilzetzki, and Kleven (2019) and Benetton (2020). This panel confirms that U.K. lenders seem to price default risk almost exclusively through LTV bands—and not through borrower-specific pricing, as it is the case in the U.S. mortgage market. Moreover, this panel ratifies our choice of modeling borrowers' choice as a discrete-choice among these LTV bands, lenders, and other product characteristics. The right panel shows that fees, which we observe in the PSD only since 2015, exhibit very limited variation across and within bands, and thus demonstrate that lenders use them mainly to extract consumer surplus.

D Model: Additional Results

In this Appendix, we provide the exact formulas of the demand elasticities and consumer surplus.

Demand elasticities. The derivatives of the individual loan demand with respect to the interest rate and the fee, respectively, equal

$$\frac{\partial q_{ijmt}}{\partial r_{jt}} = -\left(1+\alpha_m\right)\frac{q_{ijmt}}{r_{jt}}, \tag{28}$$

$$\frac{\partial q_{ijmt}}{\partial f_{jt}} = -\frac{\psi_m}{Y_i - f_{jt}} q_{ijmt}. \tag{29}$$

The derivatives of the product demand equal

$$\frac{\partial s_{ijmt}}{\partial r_{jt}} = -\alpha_m \exp\left(\delta_{jmt}+\zeta_i\right)\left(\frac{1-s_{ijmt|j\in J_i}}{\rho_m} + s_{ijmt|j\in J_i} s_{i0mt}\right)\frac{s_{ijmt}}{r_{jt}}, \tag{30}$$

$$\frac{\partial s_{ijmt}}{\partial f_{jt}} = -\frac{\gamma_m}{\left(Y_i - f_{jt}\right)^{\psi_m}}\left(\frac{1-s_{ijmt|j\in J_i}}{\rho_m} + s_{ijmt|j\in J_i} s_{i0mt}\right) s_{ijmt}. \tag{31}$$

Individual elasticities follow from equations (28)-(31). We then compute the elasticities at the product-market-quarter level by averaging across households in each market m and quarter t.

Consumer Surplus. We calculate individual consumer surplus as

$$\begin{aligned} CS_{imt} &= \frac{\log\left(\exp\left(\bar{V}_{i0mt}\right) + \exp\left(\rho_m D_{imt}\right)\right) - \bar{V}_{i0mt}}{\gamma_m Y_i^{-\psi_m}}, \\ &= \frac{\log\left(1 + \exp\left(\rho_m D_{imt} - \bar{V}_{i0mt}\right)\right)}{\gamma_m Y_i^{-\psi_m}}, \end{aligned} \tag{32}$$

where $\bar{V}_{i0mt}$ and D_{imt} are defined in equations (16) and (20), respectively. Although the marginal utility of income is not constant across alternatives, we use $\gamma_m Y_i^{-\psi_m}$ to approximate it. Average consumer surplus equal

$$E(CS_{imt}) = \frac{\sum_m \sum_{i\in I_{mt}} CS_{imt}}{\sum_m I_{mt}}. \tag{33}$$

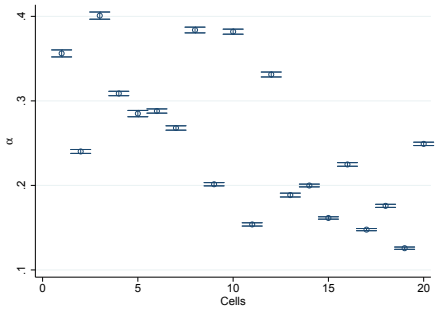
E Estimation: Additional Results

Figure E1 presents the point estimates and 95 percent confidence intervals of the demand parameters of each group. Groups are ordered as in Tables 8 and 10; e.g., group 1 comprises young, low-income households in the London region.

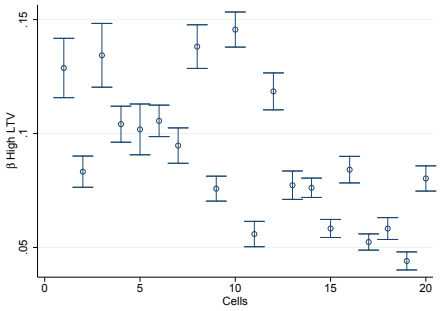
Table E1 reports the coefficient estimates of a regression equation similar to (26) using the estimated application cost a_{ij} as the dependent variable (rather than the marginal cost mc_{jt}). It is interesting to note that we do not find any evidence that the FLS program affected application costs; this provides a useful placebo test of our analysis, since lenders' costs of processing mortgage applications should be unaffected by changes in funding costs due to the FLS.

Table E2 reports the coefficient estimates of the marginal cost equation (26) using a continuous measure of FLS drawings, Q_{lt}^F, rather than the indicator variable $\mathbb{1}\{Q_{lt}^F > 0\}$ used in Table 6. The point estimates confirm that larger FLS drawings lowered lenders' funding costs more, though some estimates are noisier than those reported in Table 6; this may suggest that FLS drawings had slightly different intensive vs. extensive margin effects on lenders' costs.

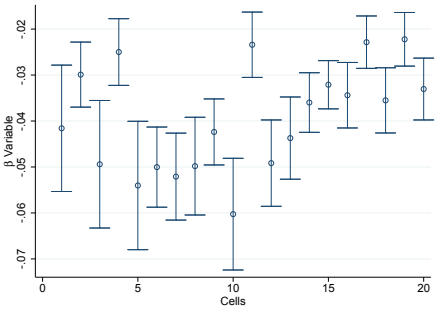
Figure E1: Demand Estimates



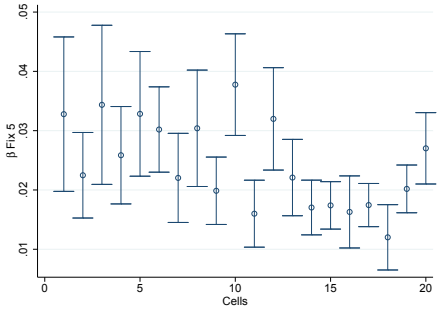
(a) Interest Rate (α_m)



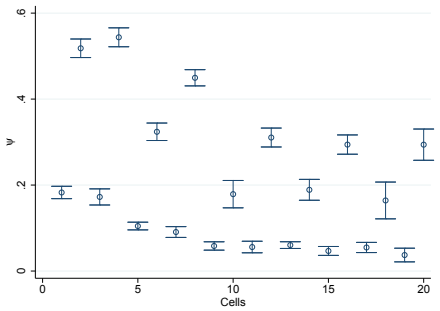
(b) High LTV ($\beta_{HighLTV}$)



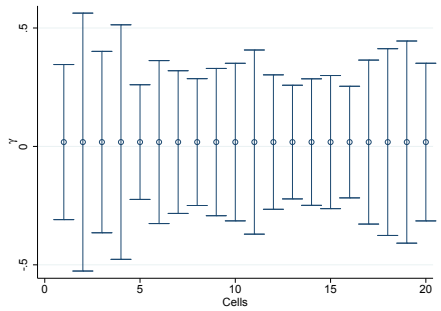
(c) Two-year Fixed ($\beta_{\tau=2}$)



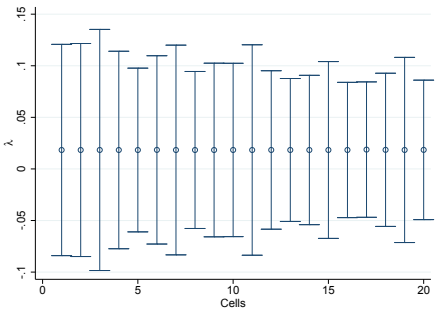
(d) Five-year Fixed ($\beta_{\tau=5}$)



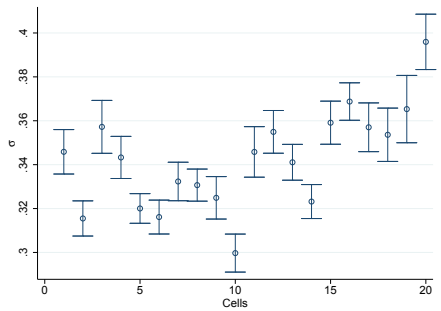
(e) Concavity in Income (ψ)



(f) Income and Fees, Product Demand (γ)



(g) Branches (λ)



(h) Standard Deviation of η (σ_η)

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

Table E1: The FLS and Application Costs

	FLS Flow					FLS Stock				
	(1) OLS	(2) FS	(3) IV	(4) FS	(5) IV	(6) OLS	(7) FS	(8) IV	(9) FS	(10) IV
FLS										
Drawing flow > 0	0.064		0.168		0.017					
	(0.150)		(0.673)		(0.672)					
Cumulative drawing flow > 0						-0.242		-0.099		-0.213
						(0.326)		(0.656)		(0.690)
Supply shifters										
Risk weights	1.386	-0.286**	1.397	-0.301**	1.381	1.477	0.320*	1.419	0.313*	1.465
	(2.977)	(0.136)	(2.954)	(0.137)	(2.959)	(3.064)	(0.168)	(3.010)	(0.169)	(3.020)
Swap rates	0.153	-0.138*	0.175	-0.138*	0.142	0.092	-0.141**	0.119	-0.144**	0.097
	(0.360)	(0.073)	(0.365)	(0.074)	(0.359)	(0.330)	(0.063)	(0.365)	(0.062)	(0.355)
Mortgage characteristics										
High LTV	0.034	0.024*	0.033	0.024*	0.035	0.031	-0.013	0.033	-0.012	0.031
	(0.266)	(0.013)	(0.262)	(0.013)	(0.263)	(0.270)	(0.017)	(0.270)	(0.017)	(0.270)
Variable rate	-0.141	0.017	-0.142	0.014	-0.141	-0.140	0.011	-0.140	0.009	-0.140
	(0.187)	(0.038)	(0.188)	(0.037)	(0.188)	(0.188)	(0.022)	(0.187)	(0.022)	(0.188)
Fix 5 years	-0.521**	0.134**	-0.540**	0.133**	-0.513**	-0.478**	0.106***	-0.497**	0.107***	-0.482**
	(0.243)	(0.050)	(0.242)	(0.051)	(0.240)	(0.227)	(0.037)	(0.227)	(0.036)	(0.224)
Bank characteristics										
Sight deposits	-3.942	-0.441	-4.095	-0.731	-3.873	-3.278	1.203	-3.615	1.027	-3.345
	(3.805)	(0.771)	(3.377)	(0.795)	(3.354)	(3.388)	(0.971)	(3.419)	(1.008)	(3.234)
Time deposits	1.030	0.755	0.967	0.725	1.059	1.393	1.139	1.202	1.115	1.355
	(3.552)	(1.031)	(3.407)	(1.038)	(3.400)	(3.516)	(1.396)	(3.051)	(1.404)	(3.008)
Capital ratio	-4.531	-2.446	-4.043	-2.378	-4.751	-5.932	-3.279**	-5.281	-3.179*	-5.802
	(7.731)	(1.590)	(8.306)	(1.606)	(8.385)	(7.370)	(1.583)	(8.746)	(1.593)	(8.908)
Assets	-2.378	0.233	-2.404	0.220	-2.366	-2.598*	-0.929**	-2.458*	-0.916**	-2.570*
	(1.464)	(0.314)	(1.522)	(0.317)	(1.514)	(1.479)	(0.362)	(1.434)	(0.366)	(1.476)
Excluded instruments										
Past Mortgages (number)		-1.498***		-1.589***			-1.040**		-1.126***	
		(0.385)		(0.391)			(0.404)		(0.397)	
Past Mortgages ($)		1.434***		1.529***			0.914**		0.999**	
		(0.356)		(0.362)			(0.385)		(0.378)	
Net income (change log)		-8.305***					-5.594***			
		(2.665)					(2.044)			
Property value (change log)		6.343**					4.988***			
		(2.570)					(1.490)			
PTI (change log)				8.383***					3.619**	
				(3.086)					(1.493)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal cost (mean)	1.02	0.21	1.02	0.21	1.02	1.02	0.42	1.02	0.42	1.02
F statistic			7.23		7.28			4.69		3.46
Adjusted R^2	0.25	0.56	0.25	0.56	0.25	0.25	0.84	0.25	0.84	0.25
Observations	511	511	511	511	511	511	511	511	511	511

Note: The dependent variable is the application cost. Standard errors are clustered at the product level.

Table E2: The FLS and Marginal Costs, Alternative Specification

	FLS Flow					FLS Stock				
	(1) OLS	(2) FS	(3) IV	(4) FS	(5) IV	(6) OLS	(7) FS	(8) IV	(9) FS	(10) IV
FLS										
Drawing flow (£B)	-0.004		-0.669		-0.453					
	(0.023)		(0.499)		(0.394)					
Cumulative drawing flow (£B)						-0.021		-0.167**		-0.211***
						(0.021)		(0.066)		(0.079)
Supply shifters										
Risk weights	4.016**	-1.179**	3.258*	-1.201**	3.504**	4.038**	0.331	4.155***	0.297	4.190***
	(1.556)	(0.462)	(1.672)	(0.465)	(1.646)	(1.550)	(0.988)	(1.570)	(0.997)	(1.582)
Swap rates	0.353*	-0.000	0.334	0.007	0.340*	0.352*	0.125	0.346*	0.125	0.344*
	(0.194)	(0.128)	(0.212)	(0.129)	(0.204)	(0.194)	(0.270)	(0.199)	(0.270)	(0.202)
Mortgage characteristics										
High LTV	0.674***	0.092**	0.734***	0.092**	0.715***	0.674***	0.014	0.672***	0.016	0.671***
	(0.151)	(0.043)	(0.163)	(0.043)	(0.157)	(0.151)	(0.090)	(0.152)	(0.091)	(0.152)
Variable rate	-0.193*	0.024	-0.178	0.027	-0.183*	-0.191*	0.090	-0.179*	0.096	-0.175*
	(0.102)	(0.042)	(0.110)	(0.042)	(0.106)	(0.102)	(0.068)	(0.102)	(0.069)	(0.102)
Fix 5 years	0.297**	0.010	0.312**	0.006	0.307**	0.297**	-0.061	0.300**	-0.060	0.301**
	(0.141)	(0.067)	(0.149)	(0.067)	(0.145)	(0.141)	(0.146)	(0.143)	(0.146)	(0.144)
Bank characteristics										
Sight deposits	-3.574**	6.484***	1.269	6.340***	-0.305	-3.454**	-0.830	-2.438	-0.461	-2.137
	(1.404)	(1.948)	(4.175)	(1.982)	(3.187)	(1.406)	(4.373)	(1.650)	(4.315)	(1.758)
Time deposits	-4.065**	7.010***	0.621	6.952***	-0.902	-3.581**	23.291***	-0.094	23.241***	0.941
	(1.650)	(1.449)	(3.924)	(1.479)	(2.932)	(1.644)	(2.763)	(2.168)	(2.802)	(2.309)
Capital ratio	7.565**	-21.734***	-7.661	-22.123***	-2.712	6.593*	-40.295***	-0.659	-41.103***	-2.811
	(3.564)	(3.682)	(11.667)	(3.757)	(10.167)	(3.777)	(7.876)	(4.560)	(8.060)	(5.102)
Assets	3.034***	-1.029	2.281**	-1.158	2.526***	2.970***	-2.409	2.508***	-2.579	2.371***
	(0.749)	(0.753)	(0.924)	(0.781)	(0.915)	(0.760)	(1.701)	(0.767)	(1.768)	(0.810)
Excluded instruments										
Past Mortgages (number)		-0.857		-0.762			-7.251***		-6.832***	
		(0.891)		(0.865)			(1.742)		(1.668)	
Past Mortgages ($)		0.754		0.674			6.509***		6.111***	
		(0.864)		(0.841)			(1.700)		(1.626)	
Net income (change log)		-5.212*					13.504**			
		(2.668)					(6.008)			
Property value (change log)		-3.494					-33.144***			
		(4.879)					(8.349)			
PTI (change log)				11.535**					-14.276	
				(4.709)					(8.690)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lender f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal cost (mean)	3.21	0.42	3.21	0.42	3.21	3.21	1.17	3.21	1.17	3.21
F statistic			2.82		3.44			9.16		10.20
Adjusted R^2	0.56	0.52	0.27	0.52	0.42	0.56	0.71	0.53	0.71	0.50
Observations	1,097	1,097	1,097	1,097	1,097	1,097	1,097	1,097	1,097	1,097

Note: The dependent variable is the marginal cost of lending. Standard errors are clustered at the product level.