

Mortgage Pricing and Monetary Policy[†]

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This paper examines how central bank policies influence mortgage pricing in the United Kingdom. It shows that lenders price discriminate by offering two-part tariffs of interest rates and origination fees, and during unconventional monetary policies like the Funding for Lending Scheme, lenders reduced interest rates while increasing fees. Using a model of mortgage demand and lender competition, we find that central bank policies increased mortgage lending. Additionally, banning origination fees would reduce lending, as fees help lenders capture surplus while allowing them to price discriminate across borrowers with different sensitivities to rates and fees. (JEL E43, E52, E58, G21, G28, R31)

In the aftermath of the 2007–2009 financial crisis, central banks around the world sought to offset the recessionary effects of the shock by cutting their policy rates and by designing new, unconventional policies, including those that acted through credit and housing markets: the US Federal Reserve QE1 and QE3, the European Central Bank (ECB) Targeted Longer-Term Refinancing Operations, and the Bank of England Funding for Lending Scheme, among others. The main goal of these unconventional policies was to make it cheaper for lenders to access funds and, in turn, “enhance the functioning of the monetary policy transmission mechanism by supporting lending to the real economy” (ECB press release, June 5, 2014).

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

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

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

These rich data allow us to provide new evidence on lenders' pricing strategies, most notably their pervasive use of menus of two-part tariffs that combine origination fees and interest rates. The pricing literature shows that indirect (i.e., second-degree) price discrimination through menus of two-part tariffs allows sellers to segment heterogeneous buyers and extract surplus from them (Wilson 1993). In the mortgage market, lenders observe some of this heterogeneity, but they may not be able (or do not want, e.g., as in Rotemberg 2011) to directly condition their prices on observable demographic characteristics, such as income, age, or geographic region. However, this heterogeneity leads different borrowers to select different loan amounts, and thus, menus of two-part tariffs effectively allow lenders to price discriminate by offering nonlinear prices and quantity discounts.

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

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

The estimation of demand suffers from traditional endogeneity concerns arising from the simultaneity of the discrete-continuous choice and from omitted variables correlated with the endogenous prices. To address these issues, we exploit our individual loan-level data to estimate the joint likelihood of the discrete-continuous problem with a rich set of product-market fixed effects that fully account for selection and

endogeneity in mortgage pricing. This joint likelihood, along with cost shifters due to risk weights and capital requirements, following the insightful papers of Benetton (2021) and Robles-Garcia (2018), allows us to estimate borrowers' sensitivities to interest rates and fees, among other parameters.

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

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

Nevertheless, the identification of the effect of the FLS on lenders' costs still faces one main challenge. Lenders' decisions to draw on FLS funds could be correlated with potentially unobservable time-varying determinants of their marginal costs. For example, lenders that otherwise would have high unobservable determinants of funding costs have stronger incentives to use FLS facilities. To address this endogeneity concern, we implement an instrumental variable approach that exploits the FLS design, thereby following the intention-to-treat literature (Imbens and Angrist 1994). Specifically, we use lenders' FLS initial borrowing allowance as an instrument for their use of FLS facilities; each bank could borrow an initial amount of up to 5 percent of its stock of existing loans (as of June 2012) to the real economy (Churm et al. 2012).

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

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

¹For 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 et al. 2019).

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

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

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

The remainder of the article is organized as follows. Section I highlights our main contributions and relates them to prior literature. Section II describes the data sources and provides descriptive evidence on the UK residential mortgage market. In Section III, we develop a structural model of mortgage credit demand and supply, which is affected by central banks' facilities. Section IV describes our estimation approach and the identification strategy. Section V presents our estimation results. In Section VI, we perform counterfactual analyses. Section VII concludes. In the Supplemental Appendixes, we provide more details on our estimation dataset, institutional background, additional descriptive evidence, some model derivations, and further results of the estimated model.

I. Related Literature

This paper contributes to several strands of the literature. First, several papers study the aggregate and distributional impact of policy interventions introduced in the aftermath of the financial crisis in credit markets, with a focus on US mortgage markets. Among these, Di Maggio et al. (2017) study the effect of the reduction of the Federal Reserve policy rate on mortgage borrowers' leverage, and Di Maggio, Kermani, and Palmer (2020) analyze the transmission of large-scale asset purchases by the Federal Reserve to borrowers' refinancing propensity. Particularly related to our paper is Buchak et al. (2024), who build a model of competition between banks

and shadow banks in US mortgage markets to examine the effects of quantitative easing. Our paper shares with that of Buchak et al. (2024) the attention to lender competition with heterogeneous borrowers. However, we tailor our model to the UK mortgage market (in which shadow banks and securitization play a minor role) and use it to study the effects of the Bank of England's unconventional monetary policy on market equilibrium, with a special focus on the structure of mortgage pricing.

Second, understanding consumers' and lenders' behaviors in mortgage markets and, more generally, in retail financial markets has been an important topic in economics in recent years. Several papers examine borrowers' choices and documented limited search, mistakes, and inertia (e.g., Agarwal, Ben-David, and Yao 2017; Andersen et al. 2020; Belgibayeva et al. 2020; Woodward and Hall 2012). Other papers study adverse selection by exploiting rich micro data on borrowers' choices and ex post outcomes, such as default (e.g., Adams, Einav, and Levin 2009; Crawford, Pavanini, and Schivardi 2018; Cuesta and Sepúlveda 2021; Einav, Jenkins, and Levin 2012; Nelson 2023). Other papers demonstrate how lenders may gain from borrowers' limited financial sophistication (e.g., Gurun, Matvos, and Seru 2016) or how different lenders specialize in different segments of the market (e.g., Buchak et al. 2018). Benetton (2021) and Robles-Garcia (2018) develop and estimate equilibrium models of the UK mortgage market to study the effects of lenders' capital regulations and those of brokers, respectively, on market outcomes.² Our equilibrium model builds on Benetton (2021) and Robles-Garcia (2018), and we use it to study borrowers' choices and lenders' two-part pricing when central bank policies affect lenders' funding costs. In doing so, we contribute to an emerging literature that estimates equilibrium models of retail financial markets, such as Mexican private pension markets (Hastings, Hortaçsu, and Syverson 2017), Canadian mortgage markets (Allen, Clark, and Houde 2019), US car loan markets (Einav, Jenkins, and Levin 2012; Grunewald et al. 2020), and US retail deposit markets (Aguirregabiria, Clark, and Wang 2019; Egan, Hortaçsu, and Matvos 2017), among others.

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

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

³Additional differences between telecommunication markets and mortgage markets are (i) product/tariff choice and quantity/usage choice are simultaneous in mortgage markets, whereas they are sequential in telecommunication markets; (ii) telecommunication markets feature periodic subscription contracts, whereas mortgage markets feature one-off choices and thus have differential roles for consumer learning; and (iii) adverse selection concerns may be more limited in telecommunication markets than in mortgage markets.

II. Data and Descriptive Patterns

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

Product Sales Database.—The Product Sales Database (henceforth, PSD), collected by the Financial Conduct Authority (henceforth, FCA), contains data on mortgage originations. For each new mortgage originated (subject to some omissions explained below), it provides the following information: loan amount, interest rate, lender, loan-to-value (LTV) ratio, interest rate type (two-year fixed, five-year fixed, and variable are the most common), and maturity; the main borrower characteristics: age, income, and borrower type (first-time buyer, home mover, or remortgager); and property characteristics: location and transaction price. Different waves of PSD exist, as the reporting requirements have changed over time. The specific PSD for our period of interest (2010–2014) is PSD 001.

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

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

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

⁴Geographic area and borrower type account for almost all the variation in choice sets across borrowers.

belong to borrowers' choice sets because of leverage limits, such as loan-to-income or LTV constraints.

Fourth, PSD 001 does not report mortgage fees.⁵ We are able to overcome this limitation because PSD 001 reports the main product attributes of each origination, such as the borrower type (first-time buyer or home mover), lender, LTV, interest rate type, and interest rate, which allow us to recover the origination fees by matching each PSD mortgage to the corresponding mortgage product from the Moneyfacts dataset described below. More precisely, Cloyne et al. (2019); Benetton (2021); and Robles-Garcia (2018) establish that the UK mortgage market features differentiated mortgage products and posted prices at the national level.⁶ Hence, we define a product type as a combination of three nonprice attributes: (i) lender, (ii) interest rate type with fixation period, and (iii) LTV ratio band. We define a product as the combination of a product type and a pair of associated rate/fee. Given a product type and an interest rate observed in PSD 001, we can recover the corresponding origination fee in the Moneyfacts dataset. Supplemental Appendix A reports more details on the merging of these two datasets and the imputation of fees, as well as other missing attributes, in the PSD.

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

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

The Bank of England publishes quarterly data on the initial allowance, the drawing amount, and the net flows of lending of each banking group participating in the

⁵Later waves of PSD report fees from 2015, which is after the introduction of the FLS in 2012.

⁶Borrower-specific pricing, which is common in the US mortgage market, is extremely limited in the UK market. Moreover, lenders post identical prices across regions. Thus, a regression of the loan-level rate on interacted product type-month fixed effects and the corresponding fee explain more than 90 percent of the variation in our PSD sample.

⁷In response to the economic crisis triggered by the global pandemic of 2020, the Bank of England launched a funding scheme similar to the FLS, and similar schemes also opened in Australia, New Zealand, Saudi Arabia, Sweden, Taiwan, and the United States. 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.

scheme. We further complement these FLS data with quarterly data on lenders' balance sheets.

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.

A. Facts about UK Mortgage Markets

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

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

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

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

The second row of each panel reports that the number of product types per month equals approximately 200 (we remind readers that we define a product as the combination of a product type and the associated interest rate/origination fee pair). This large number of products caters to borrowers with heterogeneous preferences and budgets over mortgage nonprice attributes. For example, borrowers with different expected mobility or different risk aversion may prefer different durations of their initial fixation periods, and borrowers with different wealth may choose mortgages with different maximum LTVs.

TABLE 1—PRODUCT OFFERINGS FROM MONEYFACTS

	Mean	SD	Median	P ₁₀	P ₉₀
<i>Panel A. First-time buyers</i>					
Products by month (#)	636.66	105.63	628.00	494.00	790.00
Product types by month (#)	195.80	25.00	196.00	158.00	231.00
Products by type/month (#)	3.25	3.10	2.00	1.00	7.00
Lenders by month (#)	10.92	0.28	11.00	11.00	11.00
Products by lender/month (#)	58.33	43.35	45.00	19.00	111.00
Product types by lender/month (#)	17.94	4.78	18.00	12.00	25.00
Rate	3.95	1.11	3.84	2.59	5.49
Fee	679.55	561.72	499.00	0.00	1,494.00
<i>Panel B. Home movers</i>					
Products by month (#)	610.63	109.90	600.00	466.00	784.00
Product types by month (#)	194.83	25.57	196.00	156.00	230.00
Products by type/month (#)	3.13	2.86	2.00	1.00	7.00
Lenders by month (#)	10.92	0.28	11.00	11.00	11.00
Products by lender/month (#)	55.94	40.42	45.00	19.00	101.00
Product types by lender/month (#)	17.85	4.76	18.00	12.00	25.00
Rate	3.90	1.09	3.79	2.59	5.39
Fee	723.52	561.36	795.00	0.00	1,495.00

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

The most typical product type is a two-year fixed mortgage, which means that borrowers face an interest rate that is fixed for two years and reverts to a higher level thereafter, called the standard variable rate. Lea (2010) and Badarinza, Campbell, and Ramadorai (2018) document that this dual-rate structure is common to many countries due to a combination of supply and demand factors, including banking and housing markets regulatory constraints. UK lenders hold most mortgages on their balance sheets, and thus, short-term fixed rates followed by variable ones reduce lenders' exposure to interest rate and prepayment risks, in contrast to long-term fixed-rate mortgages, dominant in the US mortgage market.⁸ Best et al. (2020); Cloyne et al. (2019); Belgibayeva et al. (2020); and Fisher et al. (2024) document that this dual-rate structure implies that approximately 70 percent of borrowers refinance exactly at the expiration of their fixation period. Hence, this frequent remortgaging activity implies that fees account for a nontrivial share of lender revenues because most borrowers pay them every two years.⁹

The third row of each panel of Table 1 reveals that the typical product type exhibits multiple fee/rate quotes, e.g., a high-fee/low-rate product and a low-fee/high-rate product. The fourth row reports that the number of lenders is stable across our sample—between 10 and 11—although at the regional level, the number of lenders is often smaller. The six largest lenders, often mentioned as the “Big 6,” have a national presence, whereas smaller lenders, such as building societies, tend to have a narrower regional reach. On average, a lender offers approximately 60 mortgage

⁸There are no agencies like the US Government Sponsored Enterprises that effectively subsidize 30-year fixed-rate mortgages and create secondary markets for mortgages and mortgage-backed securities (Acharya et al. 2011).

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

products and 20 product types, with some lenders offering more than 100 mortgage products in a given month.

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

The main driver of the variation in interest rates across products is the maximum LTV band, which is the primary way in which lenders account for borrowers' default risk. Specifically, the left panel of Figure 1 displays notable jumps in rates across mortgages with different maximum LTV bands, especially above 80 percent: mortgages with LTVs above 85 percent carry interest rates that are 200 bps higher than mortgages with LTVs below 70. This difference aligns well with the low aggregate default rates during our sample period; mortgage arrears equal 2.34 percent of total mortgage balances in 2012:II, the midpoint of our sample period, and declined steadily from 2010 to 2014, as we document in Supplemental Appendix C. More generally, the UK has recourse mortgages, which curb borrowers' incentives to default (Ghent and Kudlyak 2011).

In Supplemental Appendix C we decompose the variation in interest rates across mortgage products in the Moneyfacts dataset. The rate variation across LTV bands accounts for more than 50 percent of the residual variation after we control for aggregate changes in interest rates through monthly fixed effects. The fixation period (e.g., 2-year fixed) further captures approximately 10 percent of the rate variation across mortgage products; this is how lenders account for the interest rate risk of their mortgage books. Moreover, rate variation across lenders accounts for approximately 5 percent of the total rate variation.

Finally, UK origination fees may appear similar to US mortgage points; however, we believe that US points and UK fees play very different roles in their respective markets. Prepayment penalties have been banned in the United States since 2008 (and many US lenders did not charge them before the ban), and thus, US lenders use mortgage points to screen borrowers for their prepayment risk (Brueckner 1994; Stanton and Wallace 1998). UK lenders levy early-repayment penalties on fixed-rate mortgages, thereby directly charging borrowers who wish to exercise their prepayment option during the fixation period. For example, Figure 2 displays the website of a major UK lender. The early-repayment charge equals 3 percent on 2-year fixed mortgages and 5 percent on 5-year fixed mortgages. As a result of these steep charges, Cloyne et al. (2019) document that very few borrowers prepay their mortgages before the expiration of their fixation period.

The Prevalence of Two-Part Pricing.—Another reason for the variation in interest rates is two-part pricing. Figure 2 displays a typical example of a lender offering the same product type—that is, a 2-year fixed term, maximum LTV of 85 percent,

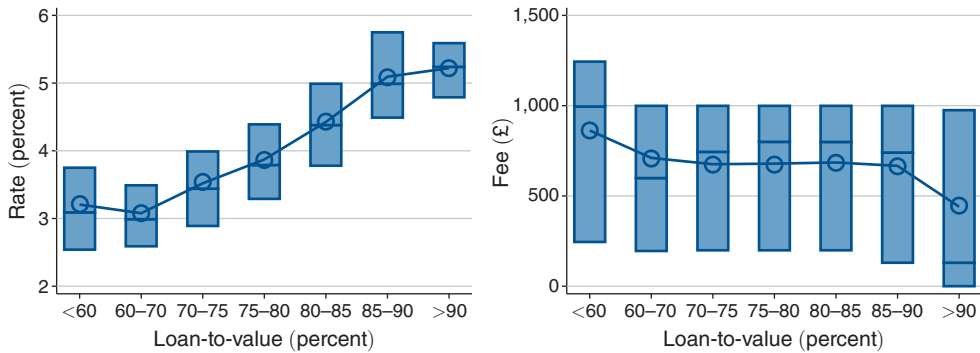


FIGURE 1. MORTGAGE PRICING

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

revert rate, additional benefits, and early repayment charges—at two distinct fee/rate quotes: a low-fee/high-rate product with a £0 fee and a 2.14 percent interest rate and a high-fee/low-rate product with a £999 fee and a 1.74 percent interest rate.

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

$$(1) \quad r_{jkt} = \eta f_{jkt} + \chi_{kt} + v_{jkt},$$

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

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

The bottom part of Table 2 reports the coefficient estimates of equation (1) when we use an indicator variable equal to one for products with no fees and zero

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%	Low rate – high fee			£999	Free valuation and £250 cashback	3% + Repay £250 cashback	£813	<input type="checkbox"/>
2 year fixed rate	85%	1.74%	n/a	4.49%	4.1%	£999	Free valuation and £250 cashback	3% + Repay £250 cashback	£823	<input checked="" type="checkbox"/>
2 year fixed rate	85%	2.14%	n/a	4.49%	4.2%	£0	Free valuation and £250 cashback	3% + Repay £250 cashback	£861	<input checked="" type="checkbox"/>
2 year fixed rate First Time Buyer Exclusive	90%	2.24%	High rate – no fee			£999	Free valuation and £250 cashback	3% + Repay £250 cashback	£871	<input type="checkbox"/>
5 year fixed rate	80%	2.44%	n/a	4.49%	4.0%	£999	Free valuation and £250 cashback	5% + Repay £250 cashback	£891	<input type="checkbox"/>

FIGURE 2. PRODUCT DEFINITION

Note: Screenshot from the website of a large lender on mortgages offered to first-time buyers in February 2017.

TABLE 2—RATE-FEE RELATIONSHIP

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

Notes: The top half reports the estimates from equation (1) using fees as a continuous explanatory variable. The bottom half 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.

otherwise as explanatory variable. The estimates in the second column imply that lenders offer products with no fees at an interest rate that is on average 34 bps higher than identical product types but with positive fees. All estimates on different subsamples show limited heterogeneity. Supplemental Appendix C.1 reports on several additional analyses on two-part pricing in our data.

Borrower Heterogeneity and Two-Part Pricing.—We now provide some descriptive evidence about the sources of borrowers' heterogeneity that may lead lenders to use two-part pricing. We proceed in two steps. We previously described the main ways through which lenders deal with default, interest rate, and prepayment risks. The first step of this analysis suggests that it is unlikely that two-part pricing is an additional tool for lenders to manage mortgage risks (see also Liu 2019). In the second step, we argue that lenders use two-part pricing to price discriminate across borrowers with heterogeneous loan amounts.

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

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

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

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

With this negative evidence in mind, we now provide some positive evidence on lenders' use of menus of two-part tariffs to price discriminate across borrowers with heterogeneous loan sizes. Differential house prices across geographic markets and within geographic markets because of different house sizes are a core dimension of heterogeneity in housing markets, and they naturally map onto heterogeneous mortgage loan amounts. Indeed, the PSD data reveal that there exists a large heterogeneity in loan amounts within all LTV bands in each market segment. Table C2 in Supplemental Appendix C reports that, whereas the average loan amounts are fairly stable across LTV bands at approximately £135,000 for first-time buyers and £175,000 for home movers with an LTV of at least 70 percent, the standard deviation

of loan amounts is highest for mortgages with LTVs between 75 and 80 percent in both segments, and it declines for mortgages in higher LTV bands. Hence, this large heterogeneity in loan amounts within LTV bands seems to provide a plausible reason for why lenders seek to segment the market by offering menus of two-part tariffs in each LTV band, even low ones.

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

Our calculations imply that approximately 54 percent of borrowers (49 and 56 percent of first-time buyers and home movers, respectively) choose the mortgage that minimizes their borrowing costs over the fixation period when a mortgage with identical nonprice attributes (e.g., same lender, LTV band, fixation period) was available; 39 percent (46 and 35 percent of first-time buyers and home movers, respectively) choose a product with a lower interest rate and a higher fee when a product with a higher interest rate and lower fee would have minimized their borrowing costs; and 7 percent (5 and 8 percent of first-time buyers and home movers, respectively) choose a product with a higher interest rate and lower fee when a product with a lower interest rate and a higher fee would have minimized their borrowing costs. These non-cost-minimizing choices, on average, increase borrowers' costs by approximately £1,000 over the fixation period. The asymmetry in borrowers' non-cost-minimizing choices in favor of mortgages with lower rates and higher fees suggests that interest rates may be more salient than fees for borrowers' choices.

Hence, our data do not allow us to establish the exact reasons for these choices that do not minimize borrowing costs. They may arise from borrowers' limited search, mistakes, and behavioral biases (Agarwal, Ben-David, and Yao 2017; Woodward and Hall 2012);¹¹ unobservable mortgage attributes (Gurun, Matvos, and Seru 2016); lenders who steer some unsophisticated borrowers toward more expensive

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

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

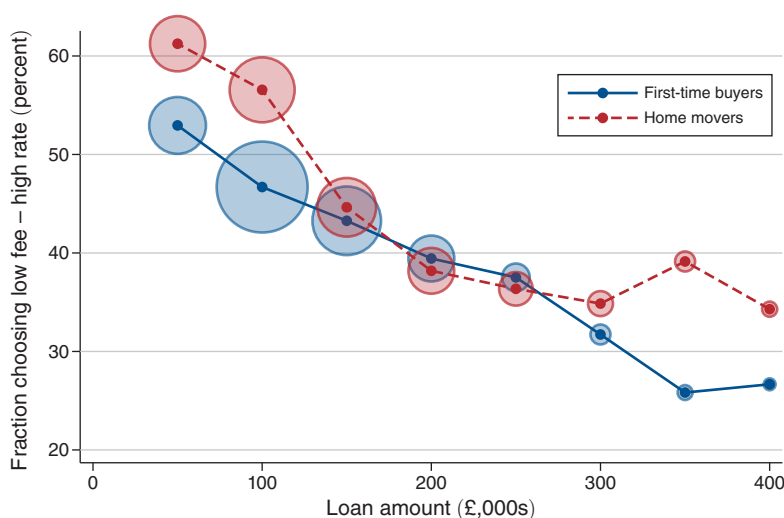


FIGURE 3. FEE CHOICE AND LOAN AMOUNTS

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

products (Guiso et al. 2022); and the interaction between borrowers' search and lenders' application approval (Agarwal et al. 2024).¹² Therefore, our model will feature observable and unobservable borrower heterogeneity, as well as observable and unobservable mortgage/lender attributes, to flexibly capture borrowers' choice of mortgage products from lenders' menus and their sensitivities to interest rates and fees. These demand estimates will be important inputs for our evaluation of how lenders' price discrimination strategies affect the transmission of central bank policies.

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

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

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

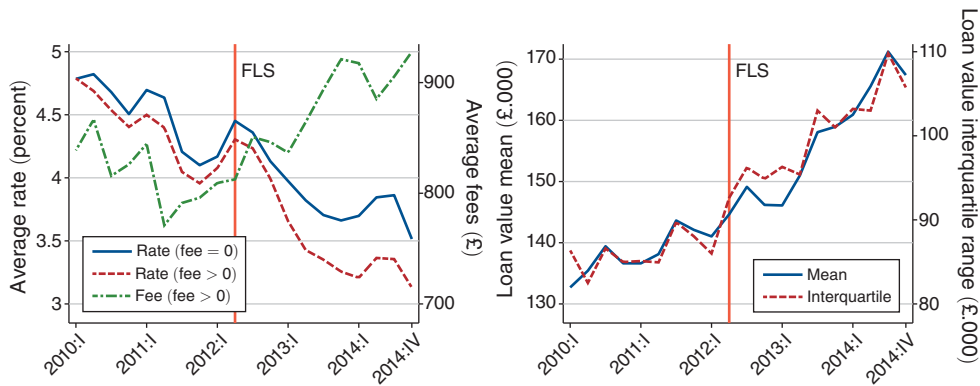


FIGURE 4. FLS AND MARKET OUTCOMES

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

of around 50 bps by the first quarter of 2014. The dashed-dotted line portrays the time series evolution of average fees for products with positive fees only. These fees were quite stable before the introduction of the FLS but increased by approximately £100 afterward.

The right panel of Figure 4 displays the time series of loan size statistics in the PSD data. The solid line shows that the average loan size of first-time buyers and home movers steadily increased in 2010–2014, most notably from the fourth quarter of 2012, likely driven by the contemporaneous decline in interest rates and increase in house prices (portrayed in the left panel of Figure C3 in Supplemental Appendix C). Moreover, the dashed line displays the interquartile range of the loan size distribution, which also increased rapidly during our sample period since house prices increased at differential rates across markets, with higher rates in London and southeast England than those in other areas.

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

B. Summary Statistics

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

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

TABLE 3—SUMMARY STATISTICS

	Mean	SD	Median	P ₁₀	P ₉₀
<i>Panel A. Demographics</i>					
Gross income (£,000s)	51.79	68.72	41.81	22.00	88.55
Age (years)	35.15	8.85	34.00	25.00	48.00
First-time buyers	0.44	0.50	0.00	0.00	1.00
London	0.14	0.35	0.00	0.00	1.00
South	0.30	0.46	0.00	0.00	1.00
Middle	0.18	0.39	0.00	0.00	1.00
North	0.24	0.43	0.00	0.00	1.00
Wales and Scotland	0.14	0.34	0.00	0.00	1.00
<i>Panel B. Choice set</i>					
Lender per market	10.14	0.77	10.00	9.00	11.00
Product per market	77.07	16.31	75.00	57.00	100.00
<i>Panel C. Choices</i>					
Loan amount (£,000s)	152.55	99.11	129.75	65.25	260.25
Loan-to-value	74.74	16.06	80.00	50.00	90.00
Loan-to-income	3.25	2.01	3.20	1.87	4.48
Maturity (years)	25.91	6.68	25.00	17.00	35.00
Big 6	0.78	0.41	1.00	0.00	1.00
Fixed rate	0.88	0.33	1.00	0.00	1.00
Rate	3.88	0.96	3.79	2.69	5.19
Fee	650.24	535.97	599.00	0.00	1,260.00

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

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

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

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

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

implementing nonlinear price schedules and quantity discounts; hence, our model includes borrowers' quantity choice as well.

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

III. A Model of the UK Mortgage Market

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

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

A. Household Mortgage Demand

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

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

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

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

where \mathbf{X}_j is a vector of time-invariant product attributes, such as the rate type, lender, and the maximum LTV; r_{jmt} is the rate and f_{jmt} is the origination fee of product j in

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

market m and quarter t ; B_{ijmt} is the branch network of the lender offering product j in the location of household i ; ξ_{jmt} captures unobservable product attributes that affect the utility of all borrowers for product j in market m and period t ; \mathbf{Y}_i is a vector of observed household characteristics, such as income and age; ζ_i denotes unobserved household characteristics, such as wealth, risk aversion, and housing preferences; θ_m collects the demand parameters common to all borrowers in market m ; and ε_{ijmt} is an idiosyncratic shock.

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

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

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

Following Benetton (2021), we allow for household-specific choice sets J_i . As we explain in Section II, we construct this choice set by comparing other households with similar observable characteristics and imposing additional restrictions based on affordability and liquidity constraints, respectively. Household i chooses mortgage product j if it delivers the highest utility of the products available in J_i and its utility is also higher than the utility of the outside option. Hence, the probability that borrower i chooses product j in market m and quarter t , given the value of his unobserved heterogeneity ζ_i , equals

$$(4) \quad s_{ijmt}(\zeta_i) = \Pr(V_{ijmt} \geq V_{i'j'mt}, \forall j' \in J_i \cup \{0\}).$$

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

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

where, with a slight abuse of notation, Y_i denotes the income of borrower i . Equations (4) and (5) uniquely define borrowers' product and loan demand, respectively, given their preferences and mortgage attributes. In practice, equation (5) anticipates one exclusion restriction we impose: lenders' networks of branches B_{ijmt} affect the utility of their mortgage products (equation (4)) but not the optimal loan amount (equation (5)).

B. Lenders' Revenues, Costs, and Pricing

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

Revenues.—The majority of UK mortgages have a discounted variable or fixed rate, which reverts to a higher standard variable rate at the end of the fixation period. Hence, borrowers have strong incentives to refinance the mortgage with a new loan

when the fixation period terminates (Cloyne et al. 2019). We focus on revenues and pricing at origination and leave to other research the analysis of remortgaging and associated pricing (Fisher et al. 2024). Hence, lenders' main revenues are the net interest income and the initial origination fee.¹⁵

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

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

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

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

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

Third, mortgages are risky assets. Three types of risks are prominent in mortgage lending: prepayment risk, interest rate risk, and default risk. As we recount in Section II, UK mortgages include sizable prepayment penalties during the initial fixation period, which minimize borrowers' incentives to prepay their mortgages. Hence, Cloyne et al. (2019) document that prepayment is extremely rare, and early-repayment charges directly cover lenders from the realization of this risk. Thus, we focus on interest rate and default risks. Critically, mortgage products with longer fixation periods carry higher interest rate risk, and those with higher LTV bands carry higher default risk. Thus, these mortgage attributes will allow us to proxy for these risks in the estimation of Section IV.

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

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

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

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

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

The introduction of the FLS potentially changes lenders’ funding costs, as they can access FLS facilities. We model this new funding option parsimoniously. Specifically, a simple revealed-preference argument implies that lenders use the optional FLS facilities to reduce their total funding costs. With some additional mild assumptions on lenders’ other liabilities, FLS funds should also reduce the marginal funding costs of lenders who choose to access them.¹⁶ More formally, marginal funding costs c_{lt}^f satisfy

$$(8) \quad c_{lt}^f \leq c_{lt}^{if} \quad \text{if} \quad Q_{lt}^{FLS} > 0,$$

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

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

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

¹⁶Marginal costs could increase if wholesale funding becomes more expensive for lenders that access the FLS facilities, but it did not happen (Churm et al. 2012).

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

In the data, we observe that UK lenders adopt national prices for identical products across geographic markets, that is, $r_{jmt} = r_{jt}$ and $f_{jmt} = f_{jt}$. Hence, lenders choose the rate r_{jt} that satisfies the following optimality condition:

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

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

Solving for the optimal interest rate yields

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

where

$$(12) \quad \widetilde{c}_{jt} = \frac{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}} c_{ijmt}}{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}}}$$

is a weighted average of borrowers' marginal costs c_{ijmt} of mortgage lending by means of product j . Hence, borrowers' selection affects lenders' costs of providing product j according to the weights $\frac{\partial q_{ijmt}^e / \partial r_{jt}}{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}}}$, which depend on the sensitivities of

their expected demand q_{ijmt}^e .¹⁷ Note that if there are no fees and no underwriting costs; all lenders offer only one product; borrowers make only the discrete product choice; and there are no selection concerns, and thus, marginal cost is constant

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

across borrowers, then equation (11) collapses to the standard markup pricing formula with one price: $r_{jt}^* = c_{jt} - \frac{\sum_i s_{ijt}}{\sum_i \frac{\partial s_{ijt}}{\partial r_{jt}}}$.

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

$$(13) \quad \frac{\partial \Pi_{jt}}{\partial f_{jt}} = \sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}} + \sum_m \sum_i s_{ijmt} \frac{\partial q_{ijmt}}{\partial f_{jt}} (r_{jt} - c_{ijmt}) + \sum_m \sum_{k \in J_{lm}} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left[\frac{f_{kt} - a_{kt}}{\tau_{kt}} + q_{ikmt} (r_{kt} - c_{ikmt}) \right] \leq 0,$$

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

$$(14) \quad \frac{f_{jt}^*}{\tau_{jt}} = \frac{\text{Underwriting cost } \frac{\bar{a}_{jt}}{\tau_{jt}}}{\tau_{jt}} - \frac{\overbrace{\sum_m \sum_i \frac{s_{ijmt}}{\tau_{jt}}}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}} - \frac{\overbrace{\sum_m \sum_i \frac{\partial q_{ijmt}}{\partial f_{jt}} (r_{jt}^* - c_{ijmt})}}{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}} - \frac{\sum_m \sum_{k \neq j} \sum_i \frac{\partial s_{ikmt}}{\partial f_{jt}} \left[\frac{f_{kt}^* - a_{kt}}{\tau_{kt}} + q_{ikmt} (r_{kt}^* - c_{ikmt}) \right]}{\underbrace{\sum_m \sum_i \frac{\partial s_{ijmt}}{\partial f_{jt}}}_{\text{Other products}}}$$

Equations (11) and (14) trace a negative relationship between the rate and the fee of each product j , consistent with the empirical evidence of Section II. Rates and fees are substitute tools for lenders; their optimal setting depends on funding costs and underwriting costs, as well as on the relative elasticities of household demand with respect to each of them.

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

IV. 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.

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

A. Demand

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

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

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

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

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

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

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

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

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

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

where

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

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

$$(21) \quad s_{ijmt}(\zeta_i) = s_{ijmt|j \in J_i}(\zeta_i) [1 - s_{i0mt}(\zeta_i)].$$

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

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

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

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

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

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

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

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

This first step yields estimates of the following parameters:

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

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

home movers, respectively.¹⁹ Because the survey has few observations only, we estimate one $\rho_m = \rho$ for all markets m .

Identification.—Estimation of the demand parameters addresses two main endogeneity concerns. First, the discrete-continuous choice generates selection bias if we do not account for the discrete product choice when we estimate the continuous quantity choice. To address this concern, we estimate the discrete and continuous choice jointly. As we explain above, the local branch network enters into the discrete choice only. Specifically, we exploit variation in the branch network, along with variation in the location of borrowers' houses at the postcode level, to identify the effect of lenders' local branch networks on borrowers' choice of lenders.

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

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

Instruments.—Our estimation deals with the possible correlation between the interest rate r_{jt} and the unobservable ξ_{jmt} in regression (17) by exploiting cost shifters of the interest rate previously employed and motivated in Benetton (2021) and Robles-Garcia (2018), that is, risk-weighted capital requirements.

Risk-weighted capital requirements affect lenders' cost of supplying a specific mortgage product, and they vary across products and across lenders, depending on whether they use an internal model or a standardized approach to measure credit risk. The adoption of an internal model versus the standardized approach to

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

assessing the risk of different assets and thus to calculate risk-weighted assets is correlated with bank size, which in turn can affect demand directly through convenience and brand value. Hence, in our demand estimation we include lender fixed effects among the time-invariant attributes \mathbf{X}_j in equation (17). We can still include lender fixed effects and use risk-weighted capital requirements as instruments because risk weights vary across products with different LTVs within lenders, and this variation across LTV is nonuniform across lenders: higher LTVs mortgages have higher risk weights for all lenders, and the difference between the risk weights on high-LTV mortgages and low-LTV mortgages is smaller for lenders using internal models than for lenders using the standardized approach, as Benetton et al. (2021) and Benetton (2021) document. In support of the exclusion restriction, Benetton (2021) (Figure 7 and Figure 4 in the Internet Appendix) shows no significant differences between lenders using internal rating-based models and lenders using the standardized approach in terms of ex ante characteristics of their mortgage borrowers, such as their age and income, and ex post mortgage performances, such as arrears and refinancing.

B. Supply

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

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

Our approach to addressing this challenge builds on the insight of exploiting "unused observables" introduced by Finkelstein and Poterba (2014). Specifically, as we explain in Section III, UK lenders post their menus of mortgage products and prices. This absence of customized prices is a pervasive (and perhaps puzzling) practice in several UK household credit and insurance markets; for example, Matcham (2024) documents it in UK credit cards. Hence, Finkelstein and Poterba (2014) test for adverse selection in UK annuities by identifying demographic characteristics that insurance companies do not use to set prices but are correlated both with insurance demand and ex post claims.

We adapt their insight to our setting by assuming that c_{ijmt} depends on borrowers' selection based on their observable characteristics \mathbf{Y}_{imt} reported in our data (age,

income, and their interaction) only. Hence, we can decompose marginal costs as follows:

$$(24) \quad c_{ijmt} = \hat{c}_{jt} + \omega'_Y \mathbf{Y}_{imt},$$

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

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

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

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

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

with the constraints $\nu_{jt} \leq 0$. Hence, the inclusion of these equations allows us to exploit all the first-order conditions to recover the cost variable \tilde{c}_{jt} and underwriting costs a_{jt} . But the inclusion adds one unknown auxiliary parameter ν_{jt} for each zero-fee first-order condition, making the system of equations underdetermined. Thus, we reduce the number of unknowns by imposing that all products offered by a lender with the same LTV band in a given quarter t have the same underwriting costs a_{jt} . We end up with an overdetermined system of equations, and we choose the solution that minimizes the sum of the squared violations of lenders' first-order conditions, subject to the constraints that the multipliers $\nu_{jt} \leq 0$.

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

$$(25) \quad \tilde{c}_{jt} = \omega_l + \omega_t + \omega'_Z \mathbf{Z}_{lt} + \omega_F \mathbf{1}\{Q_{lt}^F > 0\} + \omega'_X \mathbf{X}_j + \omega'_Y \bar{\mathbf{Y}}_{jt} + \kappa_{jt},$$

where ω_l are lender fixed effects; ω_t are quarter fixed effects; \mathbf{Z}_{lt} are lender characteristics; $\mathbf{1}\{Q_{lt}^F > 0\}$ is an indicator variable equal to one when lender l uses FLS funds in quarter t (defined more precisely below); \mathbf{X}_j are time-invariant product attributes;

$\bar{\mathbf{Y}}_{jt} = \frac{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}} \mathbf{Y}_{imt}}{\sum_m \sum_i \frac{\partial q_{ijmt}^e}{\partial r_{jt}}}$ are borrowers' observable demographic characteristics

weighted by the sensitivity of their expected borrowing q_{ijmt}^e on product j in quarter t , as in equation (12); and κ_{jt} is the structural error term capturing unobservable determinants of costs of product j in quarter t .

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

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

Identification.—The main parameter of interest in cost equation (25) is the coefficient ω^f of the indicator variable $\mathbf{1}\{Q_{lt}^F > 0\}$, which varies over time, before and after implementation of the policy, and in the cross section during the FLS period because some lenders do not draw on new FLS funds in every quarter (in the case of our first definition) or because some lenders access the FLS later than other lenders (in the case of our second definition). Hence, we can control for lender and quarter fixed effects—thereby flexibly controlling for concurrent macro shocks that could affect the funding costs of all UK lenders—and exploit within-lender variation over time to identify the effects of the FLS on lenders' costs. Nevertheless, lenders' decision whether to draw on FLS funds could be correlated with unobservable, time-varying costs κ_{lt} . Hence, we implement an instrumental variable approach that exploits the FLS design, thus following the intention-to-treat literature (Imbens and Angrist 1994).

Specifically, we use lenders' FLS initial borrowing allowance as an instrument for their use of FLS facilities; each bank could borrow an initial amount of up to 5 percent of its stock of existing loans (as of June 2012) to the real economy (Churm et al. 2012).²⁰ Thus, the instrument takes a value of zero for all lenders before the introduction of the FLS and varies across lenders after the introduction of the FLS depending on their June 2012 loan books. In practice, our instrument entails that lenders with larger allowances access FLS funds over more quarters (according to the first definition) or earlier (according to the second definition) than those with smaller allowances. Because banks face adjustment costs to their capital structure (e.g., Diamond and Rajan 2000; Lemmon, Roberts, and Zender 2008), lenders with larger allowances have larger incentives to incur these costs to access FLS funds more frequently. Benetton and Fantino (2021) exploit a similar instrument to

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

TABLE 4—DEMAND PARAMETERS

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

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

study the effects of the European Central Bank's Targeted Long-Term Refinancing Operations on bank lending to firms.

V. 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.

A. Demand

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

The signs of these parameters are broadly as expected, and their magnitudes and heterogeneity are often noteworthy. The parameter α_m , which measures the sensitivity to interest rates, displays substantial heterogeneity across groups; see top left panel of Figure E1 in Supplemental Appendix E. Parameters $\beta_m^{High\ LTV}$ and $\beta_m^{Fixed\ 5}$ indicate that borrowers prefer mortgages with higher maximum LTV limits and fixed-rate mortgages with longer fixation periods, respectively. The parameter $\tilde{\lambda}_m$ indicates that a higher density of branches in a location has a positive effect on borrowers' product demand, though this coefficient is small. The parameter ψ_m indicates a departure from quasi-linearity in income, with substantial heterogeneity in our population. The parameter σ_m implies that unobserved heterogeneity plays a moderate role among first-time buyers and a larger one among home movers; see bottom right panel of Figure E1 in Supplemental Appendix E. Finally, the parameter ρ indicates a small substitution between inside mortgage products and the outside option.

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

Given that borrowers' sensitivities to rates and fees play an important role in our counterfactual analyses, in Table 5 we report the statistics of demand elasticities to the interest rate and the origination fee. Panel A reports the elasticities of the expected demand $\sum_m \sum_{i \in I_m} q_{ijmt}^e$, which combines the continuous loan demand (panel B) and the discrete product demand (panel C). Panel A shows that, on average, borrowers are substantially more elastic to the interest rate than the origination fee. However, the elasticity with respect to the fee exhibits a larger coefficient of variation than the elasticity with respect to the interest rate. Panel B reports that,

TABLE 5—DEMAND ELASTICITIES TO RATES AND FEES

	Mean	SD	Median	P ₁₀	P ₉₀
<i>Panel A. Expected demand</i>					
Elasticity rate	-8.64	1.48	-8.60	-10.37	-6.78
Elasticity fee	-0.39	1.17	-0.15	-0.68	0.00
Rate decrease per £1,000 fee	-0.18	0.32	-0.08	-0.38	-0.04
<i>Panel B. Continuous demand</i>					
Elasticity rate	-1.22	0.02	-1.22	-1.24	-1.20
Elasticity fee	-0.38	1.16	-0.14	-0.66	0.00
Rate decrease per £1,000 fee	-0.89	1.48	-0.45	-1.84	-0.21
<i>Panel C. Discrete demand</i>					
Elasticity rate	-7.42	1.47	-7.38	-9.13	-5.58
Elasticity fee	-0.01	0.01	-0.01	-0.02	0.00
Rate decrease per £1,000 fee	-0.01	0.00	-0.01	-0.01	-0.01

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

on average, a 1 percent increase in the interest rate leads to a 1.22 percent decrease in the loan size. Panel C reports that, on average, a 1 percent increase in the rate leads to a 7.42 percent decrease in market share, which is slightly higher than previous studies of UK and US mortgage markets (Benetton 2021; Buchak et al. 2024). Hence, the product demand exhibits substantially higher elasticity to the interest rate than the continuous demand, whereas the elasticities with respect to the fee are more similar. These magnitudes suggest that borrowers may be shopping across lenders and products for a low interest rate, focusing less on the origination fee.

To gain a better sense of the relative magnitudes of these different demand elasticities with respect to rates and fees, we calculate the decrease in interest rates that fully offsets a £1,000 increase in the origination fee in borrowers’ demand functions and report it in the last row of panel A. Overall, such an increase requires an average decrease of 18 bps, with considerable heterogeneity across mortgage products: the tenth percentile equals 38 bps, the median 9 bps, and the ninetieth percentile 4 bps. Hence, the average magnitude is slightly lower than that of the empirical “exchange rate” between 28 bps and £1,000 in fees reported in Table 2, thereby corroborating that borrowers on average focus more on interest rates than on fees in their choices, and most notably in their discrete product choice, as panel C shows. Of course, some of the heterogeneity in the sensitivity to rates and fees arises because borrowers’ loan amounts differ, and thus, borrowers should rationally weigh fees and interest rates differentially. Nevertheless, the magnitudes of the variations reported in Table 5 are substantially larger than those that cost-minimization arguments imply, and Supplemental Appendix E reports additional calculations that corroborate this finding.

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

TABLE 6—THE FLS AND LENDERS' COSTS

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

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

B. Supply

Table 6 collects coefficient estimates of equation (25). The dependent variable is the estimated cost variable \tilde{c}_{jt} , and the main coefficient of interest is that of the indicator variable $\mathbf{1}\{Q_{jt}^F > 0\}$, which accounts for the effect of the FLS on lenders' costs. Table 6 reports the regressions in which $\mathbf{1}\{Q_{jt}^F > 0\}$ depends on lender l 's net

positive drawing flow on FLS funds in quarter t , whereas Table E3 in Supplemental Appendix E reports the regressions in which $\mathbf{1}\{Q_{it}^F > 0\}$ depends on lender l 's net positive drawing stock on FLS funds in quarter t . All regressions further include lender characteristics, obtained from their balance sheets, and mortgage product attributes, as well as lender and quarter fixed effects.

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

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

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

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

Interestingly, the coefficient estimates of borrowers' demographic characteristics suggest negligible selection effects. The coefficient of the weighted average borrower income is always insignificant. The negative coefficient of the weighted average age suggests that mortgage lending to younger borrowers is more costly—according to our assumptions, because of higher expected default costs. However, its magnitude is small, suggesting minimal economic relevance: the standard deviation of the weighted average borrower age across observations equals 4.18 years, and thus, the coefficient in column 3 of Table 6 means that a 1 standard deviation increase in the weighted average borrower age increases costs \tilde{c}_{jt} by 6.6 bps, or 8 percent of the standard deviation of the costs \tilde{c}_{jt} across observations, which equals 83 bps.

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

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

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

VI. Model Implications and Counterfactual Policies

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

A. *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 (2011:III) and one after the introduction of FLS facilities (2013:III). These outcomes correspond to the fitted values of the model evaluated at the estimated parameters in the two quarters. The top part of Table 7 reports the averages and standard deviations (in parentheses) of marginal costs and underwriting costs. These statistics place equal weight on each mortgage product. The comparison between the pre-FLS period and post-FLS period reveals that lenders’ average costs declined: marginal costs by 59 bps and underwriting costs by £138.²¹

²¹ Plausible explanations for the decline in underwriting costs include banks’ increased adoption of technology in mortgage underwriting, as Fuster et al. (2019) show for the US mortgage market; the increasing share of UK mortgages originated by brokers, who have lower costs than lenders (Robles-Garcia 2018); and changes in mortgage underwriting regulation (Van Dijk and Garga 2006).

TABLE 7—EFFECTS OF THE FLS ON MORTGAGE SUPPLY AND DEMAND

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

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

The middle part reports that lenders lowered their interest rates on average by 82 bps, but they increased their origination fees on average by £190 (again, these statistics weight each mortgage product equally). Moreover, the number of mortgage products also increased from 220 in the pre-FLS market to 242 in the FLS market. The bottom part of Table 7 reports that the average mortgage amount increases by approximately £23,000, or 18 percent of the 2011:III average loan amount, and the number of mortgages increases by approximately 4,000, or 24 percent of 2011:III originations.

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

controlled comparison between the market in 2011:III and a counterfactual market in which the FLS exclusively affects lenders' funding costs.

Specifically, we reduce the marginal costs \tilde{c}_{jt} of those lenders who drew FLS funds by 40 bps. We keep underwriting costs, the number of mortgage products, as well as borrower characteristics, constant at their 2011:III sample values. Lenders choose rates and fees according to the optimality conditions (11) and (14) based on their lower marginal costs because of their FLS take-up. We constrain fees to be nonnegative and set them to zero if the right-hand side of equation (14) is negative evaluated at zero. We use iterated best responses that maximize lenders' profit functions to compute the equilibrium.

Column 4 of Table 7 reports market outcomes of this case. The top part confirms that FLS facilities reduced lenders' marginal costs, on average by 35 bps (because some lenders did not access FLS funds, the reduction in average marginal costs is lower than 40 bps). The middle part of the table shows that lenders more than pass this cost reduction through to borrowers because on average, they decreased interest rates by 44 bps, implying a pass-through of $44/35 > 1$. Moreover, they increased origination fees by £237 even though underwriting costs did not change by construction. Hence, the model neatly captures the striking differential changes in interest rates and origination fees between 2011:III and 2013:III that we displayed in the left panel of Figure 4.

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

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

literature recommends caution in this interpretation of the increase in household borrowing (Heidhues and Kőszegi 2010).

B. *The Role of Fees*

Our second counterfactual case focuses on the effects of two-part pricing with rates and fees by simulating a ban on origination fees. We believe that this is of interest for at least two reasons. First, Greenwood and Scharfstein (2013) document the growth in fees associated with the expansion of household credit in an environment with declining interest rates, particularly the fees associated with residential mortgages. Section III 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 considered regulating mortgage origination fees.²² Our estimated model seems well suited to yield insights into how such regulation could affect market outcomes. In our context, studying a ban on fees allows us to understand whether two-part pricing strategies amplify the effects of central bank policies such as the FLS on aggregate lending.

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

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

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

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

First, the increase in the interest rates paid is quite heterogeneous across groups of borrowers. On average, borrowers with larger mortgage loans suffer the largest rate hikes when fees are banned because they chose products with lower rates and

²²Pickford, James. 2016. "Mortgage Lenders under FCA Review for Masking High Fees." *Financial Times*, December 12. <https://www.ft.com/content/b63cf9a8-c067-11e6-81c2-f57d90f6741a>.

higher fees in the baseline economy in which lenders can charge fees, as Figure 3 documents.

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

VII. Conclusion

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

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

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

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