The Demand for Long-Term Mortgage Contracts and the Role of Collateral *

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Abstract

Long-term fixed-rate mortgage contracts protect households against interest rate risk, yet most countries have short fixation lengths, up to five years. Using administrative data from the UK, this paper shows that the choice of fixation length is affected by the life-cycle dimension of credit risk in the mortgage market: the loan-to-value (LTV) ratio declines and collateral coverage improves over the life of the loan due to principal repayment and house price appreciation. High-LTV borrowers face a trade-off between their demand to insure against repricing, and obtaining lower credit spreads over time using shorter-term contracts. To quantify demand for longer-term contracts, I develop a life-cycle model of optimal mortgage fixation choice. With baseline house price growth and interest rate risk, high-LTV households prefer shorter-term contracts, in line with the data.

JEL classification: D15, E43, G21, G22, G5, G52

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1. Introduction

Long-term contracts offer households protection against repricing when fundamentals change (Harris and Holmstrom, 1982, 1987). The most important financial contract based on its weight in household balance sheets is the mortgage, with loan repayment over around 30 years. Yet the period over which households fix their mortgage rate is typically much lower, between two to five years in Canada, Australia and most European countries including the UK. Such short fixation periods imply frequent repricing and exposure to different sources of risk when the fixed rate expires, most prominently the risk of increasing aggregate interest rates.[1] The length over which mortgage rates stay fixed is hence an important dimension of household contract choice, but has not been studied explicitly thus far. The paper aims to fill this gap.

To provide intuition, a basic insurance framework suggests that risk-averse households prefer one long-term mortgage contract with no repricing risk, to rolling over two short-term mortgage contracts with a zero-mean risk in mortgage payments, with the same expected cost. In order to evaluate this prediction empirically, I employ granular UK administrative data. The paper generates three main findings. First, it documents a novel fact: the share of relatively long-term mortgages is decreasing in the loan-to-value (LTV) ratio, a measure of credit risk, meaning that riskier borrowers with smaller down payments insure less against interest rate risk. Second, I propose a mechanism to explain this fact, by taking into account the life-cycle dimension of credit risk in the mortgage market: over the life of the loan, the loan-to-value ratio typically declines and thus collateral coverage improves, due to principal repayment and house price appreciation. When considering a longer fixation length, borrowers trade off their regular demand to insure against repricing, to obtaining a lower credit spread over time by repricing more frequently. This matters in particular to high-LTV borrowers, who face large initial credit spreads.

As a third step, to quantitatively evaluate this trade-off, I build a life-cycle model of optimal mortgage fixation choice. The model allows me to evaluate the insurance benefit of longer-term contracts by varying households' available contract choice sets. The model suggests that high-LTV borrowers prefer shorter-term contracts under standard calibrations for house price growth and risk, and income and interest rate risk. The insurance value of longer-term contracts, measured as a consumption certainty equivalent, is around 2 to 3 times smaller for high-LTV borrowers, compared to low-LTV borrowers. The paper hence proposes a mechanism that reduces demand for longer-term contracts in high-LTV segments of the mortgage market, and

[1] The paper abstracts from mortgage contract choice trade-offs with inflation risk, which is studied in Campbell and Cocco (2003). Fixed-rate mortgages are implicitly treated as inflation-indexed, as in Campbell et al. (2021), and this assumption is discussed in more detail in the remainder of the paper.

helps explain the prevalence of relatively short mortgage fixation lengths across most countries.

I exploit the UK mortgage market setting as an ideal laboratory for mortgage fixation length choice. Mortgage contracts in the UK allow households to explicitly choose the length over which the mortgage rate stays fixed, separately from the period over which the mortgage is repaid. The choice of fixation length is difficult to isolate in the frequently-studied US market because it is confounded by the simultaneous choice of repayment window, e.g. a 15-year fixed-rate mortgage has a fixed rate for 15 years, but is also repaid over 15 years, giving rise to other choice factors over and above the insurance choice against repricing. Second, the UK allows me to study credit risk as an important pricing factor in mortgage contracts. While high-LTV mortgage issuance is common in both the US and UK, prices reflect public credit risk guarantees provided by government-sponsored entities in the US (Campbell, 2013), rather than market prices of credit risk. Lastly, the UK market structure is representative of most of the world's largest mortgage markets,[2] where the fixed rate resets to a more expensive floating rate at the end of the fixation period. These rate resets provide regular economic incentives to refinance into new fixed-rate contracts. UK mortgage rates are typically fixed for two to five years, similar to countries such as Canada, Australia and Ireland.[3]

To study contract pricing and household behavior over time, the paper utilizes two datasets provided by the Financial Conduct Authority (FCA), comprising the universe of UK residential mortgage originations, and stock of all outstanding mortgages. The full origination data is used to study contract pricing and choice. In addition, I build a panel dataset for first-time borrower cohorts between 2013 and 2017 to track contract choice and loan performance for these borrowers over time.

In simple descriptive analysis, the loan-to-value ratio plays an important role for fixation length choice. A borrower at 95% LTV is between two to three times less likely than a 70%-LTV borrower to take out a 5-year fixed-rate contract compared to a 2-year contract. LTV remains the strongest cross-sectional predictor of 5-year fixed-rate contract choice when controlling for other characteristics such as the loan-to-income ratio, borrower age, loan size and loan maturity.[4] In the UK, LTV is the main dimension along which credit risk is priced.[5] The loan-to-value

[2]Including Canada, Australia, Germany, Italy, Spain, Sweden, Denmark and Ireland.

[3]Throughout the paper, I refer to a long-"term" contract as a contract with a relatively longer fixation period, to indicate the interval between repricing. I focus on the most prevalent mortgage fixation lengths of two and five years, which make up around 90% of the UK market. UK variable-rate mortgages also feature rate resets, but take-up is very low, around 4%, in the sample period.

[4]There are no restrictions on the supply side to offer certain fixation lengths, and there are 3.6% of mortgages with fixation lengths greater than 5 years over the sample period, but which are mostly concentrated at low levels of LTV, shown in the online appendix. The pattern is also replicated in the sub-sample of borrowers who originate their loan directly, rather than via a broker.

[5]Lenders have "full recourse" in the UK, meaning they can recover losses from defaulted borrowers though their assets and incomes for up to seven years, until the debt is paid (Aron and Muellbauer, 2016), which may help explain why measures of household-specific creditworthiness such as the FICO score are only accounted for

ratio is an inverse measure of collateralization of the mortgage. The higher the LTV, the greater the loss in case of default, as the value of the house which can be seized by the lender, relative to the outstanding loan amount, decreases. Lenders charge a credit spread that is increasing and convex in the LTV ratio in the region between 70 and 95% LTV, i.e. mortgage rates are increasingly "collateral-sensitive" for an LTV above 70%. This credit spread is sizeable: For instance, the mortgage rate at an LTV of 95% is on average 220 basis points higher than at 70% LTV over the sample period.

Tracking borrower outcomes over time, I show that there is a trend decline in the loan-to-value ratio over the life of a typical mortgage loan. The numerator, the loan balance, decreases due to principal repayment, while the denominator, the value of the house, increases given positive house price growth. This implies a life-cycle dimension to credit risk in mortgage contracts, as expected losses from the perspective of the lender, and hence credit spreads, decrease over time. When households choose the fixation length for their mortgage rate, the credit spread component plays a larger role for high-LTV borrowers, in addition to the current base interest rate. High-LTV borrowers can obtain lower credit spreads when refinancing more frequently via shorter-term contracts, to price in lower levels of LTV over time. I find that households lock in similar credit spreads regardless of the fixation length, meaning that households cannot obtain these credit spread reductions ex ante. This raises the relative cost of a longer-term contract, compared to a sequence of shorter-term contracts, for high-LTV borrowers.

I illustrate the credit repricing effect on the relative cost of longer-term contracts by borrowing from the literature on government bonds (Campbell and Shiller, 1991). As a direct comparison, households can compute the expected yield difference between the longer-term mortgage contract, compared to rolling over a sequence of short-term contracts. For low-LTV borrowers, the yield difference reflects the standard bond term premium, the term premium pertaining to the riskless interest rate.[6] For high-LTV borrowers, the life-cycle dimension of credit risk has a sizeable effect on relative contract cost. Given a standard loan repayment path and calibrated expected house price growth of 2.6 percent per annum, I find that the rate on a 5-year 95% LTV contract held over 5 years would have to be 69 basis points lower than the 2-year rate at 95% LTV, since the latter is expected to be refinanced with 2-year contracts with gradually lower credit spreads. Market prices for long-term mortgage contracts are hence relatively expensive for high-LTV borrowers.

Existing work has demonstrated that long-term contracting can be affected by market imperfections, across a range of different markets including long-term care insurance and unse-

via a minimum threshold at loan application, but result in no price variation conditional on LTV (as shown by Robles-Garcia, 2020).

[6] I indeed find that this measure tracks banks' funding cost spread between longer and shorter maturity interest rate swap rates.

cured credit markets (e.g. Hendel and Lizzeri, 2003; Nelson, 2018). This paper proposes a novel explanation that reduces long-term contracting in the mortgage market, where key risks are systematic. I show that the expected cost of taking out a longer-term mortgage for high-LTV borrowers is greater than rolling over a sequence of shorter-term contracts. Due to the life-cycle trend in LTV, lenders would have to price in a forward-looking path of collateral, and implicitly bear the risk of future house price developments over the fixation horizon of the longer-term contract, in order to make these contracts attractive to high-LTV borrowers. The findings are consistent with lenders requiring compensation for a systematic source of risk, and the lack of financial instruments available to hedge aggregate house price risk, as observed by Shiller (2014) and Fabozzi et al. (2020). The findings also provide a general intuition for why the initial insurance benchmark does not hold, as long-term contracts in markets with systematic risks may command a premium above the expected cost of the short-term contract sequence.

I find less direct evidence for information frictions. Borrowers may strategically select into fixation lengths (Flannery, 1986; Diamond, 1991; Hertzberg et al., 2018) if they have private information about future repricing risks, which could be more severe at higher LTV bands. I find limited evidence for net adverse selection into longer-term contracts, in particular not at high levels of LTV. I find that ex ante measures of risk such as local house price betas are weakly negatively correlated with 5-year take-up. Ex post default rates within a given LTV band are similar across contract types, with the caveat that the sample window reflects a time period with relatively stable house price growth and low overall rates of default. A related long-term contracting problem is selective household attrition over time (Hendel and Lizzeri, 2003; Handel et al., 2015; Nelson, 2018): Households who receive better shocks ex post can leave the borrower pool over time, such that lenders retain an adversely selected pool. In contrast, I find that attrition is minimal over the initial fixation length, due to significant prepayment penalties that penalize early contract termination within the fixation window.[7]

In order to quantitatively evaluate contract choices and quantify the insurance value of longer-term contracts net of cost, I build a life-cycle model of optimal mortgage fixation choice. Throughout the life of the loan, households optimally choose between two contract fixation lengths, a novel contribution to existing models of mortgage choice.[8] Depending on the fixation length chosen, households face repricing based on realized loan-to-value ratios, driven by shocks to house prices and regular loan repayment, and shocks to aggregate interest rates. Households also optimally choose consumption over the life cycle, and face income risk. In the model,

[7]Mortgages in the UK have prepayment penalties of about 3 to 5% of the loan value throughout the initial fixation period (see e.g. https://moneyfacts.co.uk/mortgages/).

[8]These have focused on the 30-year fixed-rate contract in the US and hence do not feature contemporaneous choice throughout the 30-year repayment window, see e.g. Campbell and Cocco (2003); Campbell et al. (2021).

households trade off their regular demand to insure against repricing, against obtaining a lower credit spread over time by repricing more frequently.

I then use the model to quantify the marginal welfare benefit of adding a longer-term contract to the choice set, as a standard consumption certainty equivalent. I find that high-LTV households, evaluated at 90% LTV, have a reduced willingness-to-pay for 5-year fixed-rate contracts, compared to low-LTV households at 70% LTV. Under a baseline calibration for income, interest rates and house prices, the marginal insurance value of longer-term contracts is 0.36% of annual consumption for high-LTV borrowers, around half of that for low-LTV borrowers. I also evaluate a counterfactual 10-year fixed-rate contract, where the relative willingness to pay is lower, 0.74% for high-LTV borrowers, amounting to about a third of the 2.03% for low-LTV borrowers, meaning that take-up of high-LTV borrowers is relatively lower compared to low-LTV borrowers. When simulating contract choices, I find a life-cycle pattern in mortgage fixation choice, as optimal fixation length is decreasing in LTV. Households are increasingly likely to take out 5-year fixed-rate contracts over the life of the mortgage as LTV decreases over time, in line with the data.

The model findings suggest that there would be substantial welfare gains for high-LTV households if they could access longer-term mortgages that lock in the base interest rate while adjusting for the trend in credit spreads, and help explain the missing (or very small) markets for even longer mortgage fixation lengths beyond 5 years when high-LTV lending is common.

The paper proposes a mechanism that reduces demand for longer-term mortgage contracts and hence risk-sharing in high-LTV segments of the mortgage market, which is relevant for the continuing policy debate on optimal mortgage contract and market design (Campbell, 2013; Eberly and Krishnamurthy, 2014; Mian and Sufi, 2015; Greenwald et al., 2021; Piskorski and Seru, 2018). In the US, such risk-sharing is done via public credit risk guarantees by government-sponsored entities, and may help explain why it is one of the few mortgage markets in the world where high-LTV borrowers take out 30-year fixed-rate contracts.

The results are further important from a monetary policy perspective. The relative cost of long-term contracts for high-LTV borrowers influences the length over which their mortgage rates are locked in, and hence the monetary transmission mechanism (Beraja et al., 2019; Wong, 2019; Andersen et al., 2020). The paper suggests that any mortgage policy interventions should be state-dependent: Having high-LTV borrowers take out shorter-term fixation lengths may improve pass-through when interest rates decrease, but may be more concerning from a financial stability perspective at a time of rising interest rates, as these high-LTV borrowers are less insured against interest rate rises.

1.1. Related Literature

The paper contributes to several strands of literature. Household choice of mortgage fixation length is an important part of the household risk management problem. This paper adds to existing work which has focused on the US institutional framework (Campbell and Cocco, 2003) and the choice between 30-year fixed and adjustable-rate mortgages (Koijen et al., 2009; Badarinza et al., 2018). The most closely related papers are by Dunn and Spatt (1985, 1988) and Mayer et al. (2013) who study the risk-sharing effects of enforcing commitment with long-term mortgage contracts via prepayment penalties in the US context. My findings suggests that pooling in longer-term contracts in the high-LTV segment may be difficult to sustain under market pricing of credit risk, even with binding prepayment penalties, as relative pricing provides strong incentives for high-LTV borrowers to choose shorter-term contracts.

The findings support research emphasizing the role of house price risk and collateral sensitivity for household behavior in the mortgage market (Palmer, 2015; Fuster and Willen, 2017; DeFusco and Mondragon, 2018; Ganong and Noel, 2020). Frequent repricing has large effects on mortgage rates for high-LTV borrowers, which are very collateral-sensitive, overriding their insurance demand against interest rate risk. The paper emphasizes the interactive effects of possibly competing sources of repricing risk on mortgage contract choice.

The paper further quantifies the willingness-to-pay for longer-term mortgage contracts using comprehensive micro-data and a life-cycle model of mortgage fixation choice, building on influential work on mortgage choice by Campbell and Cocco (2003), and similar approaches in other insurance markets (see e.g., Brown and Finkelstein, 2008) to estimate counterfactual demand for non-traded or missing markets, and helps explain the lack of even longer mortgage fixation lengths. The goal of the paper is thus complementary to papers that study optimal mortgage contract design in general equilibrium (Guren et al., 2021; Campbell et al., 2021; Greenwald et al., 2021).

Lastly, the findings relate to a broader literature on long-term contracting and contract choice given dynamic repricing risks (Harris and Holmstrom, 1982, 1987; Hendel and Lizzeri, 2003; Handel et al., 2015, 2017; Hertzberg et al., 2018; Nelson, 2018).[9] Previous papers have studied the front-loaded nature of pricing (e.g. Hendel and Lizzeri, 2003) to overcome dynamic contracting problems, as well as the pricing of callable bonds, i.e. bonds that can be prepaid (Becker et al., 2021). In the mortgage market setting with prepayment penalties, I show that the trend in credit spreads reduces take-up of long-term contracts by high-LTV borrowers, despite effective commitment over the fixation horizon. This likely reflects the importance of house

[9]Also referred to as rollover risk in corporate finance (e.g., Acharya et al., 2011; He and Xiong, 2012; Choi et al., 2018), and reclassification risk in insurance markets (e.g., Handel et al., 2015; Hendel, 2017).

price risk and lender willingness to bear a source of systematic risk (Shiller and Weiss, 1999; Shiller, 2014) in this market.

This paper is organized as follows. Section 2 introduces the institutional framework and data. Section 3 outlines the empirical analysis. Section 4 develops the model and discusses results, and Section 5 concludes.

2. Institutional Setting and Data

This section provides background on the UK mortgage market and the typical mortgage contract structure, and provides a brief summary of the data.

2.1. UK Fixed-Rate Mortgages and Institutional Setting

Fixed-Rate Mortgage Contract Structure. The dominant mortgage product in the UK is a fixed-rate contract that resets automatically to a revert rate at the end of the initial fixation period, for the remainder of the loan maturity, unless the borrower refinances into a new contract.[10] The initial fixation period is typically two or five years, which account for 87% of all contracts. The revert rate is priced at a spread to a floating base rate, the Bank of England's Bank Rate, and this spread has been around 300 to 400 basis points since 2009. Figure A.1 in the online appendix illustrates the payment profile for a typical fixed-rate mortgage and is further explained below. The rate reset provides a regular economic incentive to refinance into another fixed rate contract,[11] in which case the contract is repriced.[12] 80 to 90% of first-time buyers refinance within six months of the reset date, consistent with findings by Cloyne et al. (2019), as the loan balance especially in the initial years since loan origination is usually sufficiently high to warrant refinancing.

Mortgage Contract Characteristics. Mortgage contracts typically specify the maturity over which the loan is repaid, most commonly between 25 and 35 years; the interest rate; initial fixation period; the rate type over the initial period (fixed or floating); and prepayment penalty due if households prepay and terminate the contract within the initial fixation period. Mortgage

[10]The paper focuses on fixed-rate as opposed to floating or adjustable-rate mortgages, but the contract structure is analogous in adjustable-rate mortgages which reset at regular time periods. In the UK, adjustable-rate mortgages feature an initial spread over a floating base rate, which can reset to a larger spread after an initial discounted period and hence provides similar incentives to refinance intermittently. Over the sample window, the share of floating-rate mortgages is very low, at about 4% of all mortgages originated.

[11]Depending on other factors that affect optimal refinancing such as loan size, the interest rate incentive, and the cost of refinancing (Agarwal et al., 2013; Fisher et al., 2021).

[12]In the US mortgage market, this type of product would typically be referred to as a "hybrid" adjustable-rate mortgage (ARM).

interest rates differ by rate type, loan-to-value ratio, and rarely borrower type (first-time borrower, home mover or refinance), but not other borrower characteristics. Borrowers go through an approval process where lenders screen applications using minimum criteria related to the current age, age at loan repayment, loan maturity, loan-to-income ratio, credit score and credit history. Subject to passing these lender criteria, risk-based pricing is focused on the LTV dimension, in contrast to the US, which features variation in mortgage guarantee fees along the LTV and FICO score dimensions (Gerardi, 2017). UK mortgage rates are priced across LTV bands in steps of five percentage points, starting from an LTV pricing threshold of 60 to 70%, up to an upper bound of 95% LTV.[13] Offered rates apply across the UK and are not further personalized.

Repricing. Around two thirds of mortgages are refinanced with their existing lender, while the remaining third change lenders. Lenders typically do not carry out new credit or affordability checks for their existing customers (FCA, 2018), meaning that the majority of households only faces repricing risk based on aggregate interest rates and LTV, rather than changes to household-specific creditworthiness and income. For these borrowers, the property value is also typically not externally re-appraised but adjusted based on changes to local property prices.

Prepayment Penalties. Mortgage contracts feature prepayment penalties over the initial fixation period in case of early repayment, and vary from around 3 to 5% of the outstanding loan balance. Some prepayment terms offer free partial early repayment, such as 10% of the loan value per year. Prepayment terms are not collected as part of the administrative mortgage data, but research using complementary data by a private data provider on the universe of mortgage contracts on offer shows that they do not vary substantially and systematically over time or across lenders (Liu, 2019).

2.2. Dataset Construction

Data Overview. This subsection describes the data and provides a brief overview of the main dataset construction. A more detailed description is provided in the online appendix (section B). My main data source is the Product Sales Database (PSD), a comprehensive loan-level dataset on residential mortgages in the UK, collected by the Financial Conduct Authority (FCA), and accessed via a data-sharing agreement with the Bank of England. The data comprise the universe of new loan originations at quarterly frequency (PSD001), and also track the stock of all outstanding mortgage loans issued by all regulated financial institutions in the UK at semi-annual frequency (PSD007). The datasets have been used in a range of academic studies (e.g.

[13] The resulting step function pricing schedule can be verified in posted prices on offer, as well as realized interest rates (see e.g. Best et al., 2020).

Cloyne et al., 2019; Best et al., 2020; Robles-Garcia, 2020; Belgibayeva et al., 2020; Benetton, 2021). I use both the PSD001 loan origination data from January 2013 to December 2017, and a merged subset of the data that combines the information at loan origination with the stock of all outstanding mortgages between 2015 and 2017 in the PSD007 data, which further includes information on refinancing status, interest rate paid and loan performance reported in semi-annual snapshots. The merged data forms a borrower-level panel that is tracked at semi-annual frequency.

Data on New Mortgage Originations (PSD001). The dataset collects detailed borrower characteristics such as income, age, address, loan amount, property value, and detailed loan characteristics such as the loan maturity, interest rate, fixed-rate window, and which lender originated the mortgage. I use the origination data between 2013Q1 to 2017Q4 for the pricing analysis and results that do not require the borrower panel dimension, containing around 2.9 million loans. I further use the data to identify first-time buyer cohorts who newly originate their mortgage between 2013H2 to 2015H1 to create the borrower panel. The origination data prior to 2015H1 does not require to report the fixed-rate window, so I do not observe the fixed-rate window for about 40% of first-time borrowers in this time period. The sample for which fixed-rate windows are observed appears to be a highly balanced sample compared to where it is not observed, as noted by Best et al. (2020) and demonstrated in Table B.7 in the online appendix. The sample for which the fixed-rate window is observed contains 414,643 first-time borrowers.

Data on the Stock of All Outstanding Mortgages (PSD007). The stock data contains information on the current interest rate type, current interest rate paid, current loan amount, current lender, and whether the loan is in arrears. I create the borrower panel by merging first-time buyer cohorts from the origination data with stock data waves 2015H1 to 2017H2, to track refinancing behavior and outcomes over time.[14]

Data Merge. The origination and stock datasets do not have unique borrower identifiers, but a borrower can be identified up to an (anonymized) date of birth and six-digit postcode, which is approximately the building block in which a UK household resides. The merge using this borrower identification is almost comprehensive, with only 1.8% of first-time borrowers in 2015H2 not matched to the stock data in 2015H2, which provides an estimate of unmatched observations driven by pure merging error. This results in a panel of around 2.8 million borrower-half-year observations. Lastly, I supplement the merged dataset with administrative data on UK house

[14] This builds on and extends previous research that has used the loan origination data (Cloyne et al., 2019), and a merged snapshot of the mortgage stock data (Belgibayeva et al., 2020).

prices from HM Land Registry, using house price indices at local-authority administrative unit-level (with data going back to 1995), and merging these at the local-authority level based on borrower location.

3. Mortgage Contract Choice and the Life Cycle of Credit Risk

This section illustrates patterns in household fixation length choice and the role of the loan-to-value ratio. It introduces two main findings. First, the probability of choosing a 5-year, relative to a 2-year fixed-rate mortgage contract is decreasing in LTV. Second, there is a life-cycle dimension of credit risk in the mortgage market due to loan amortization and positive house price growth, reducing the LTV ratio and hence improving the collateralization of the loan over time. Second, this downward trend in expected credit risk and hence credit spreads raises the expected cost of a 5-year, compared to a sequence of 2-year fixed-rate contracts, where credit spreads are repriced over time.

3.1. Mortgage Fixation Length Choice and the Role of LTV

Which households choose a 5-year, rather than a 2-year fixed-rate contract? I estimate a linear probability model for choosing a 5-year fixed-rate contract relative to a 2-year contract, based on a range of household and loan characteristics. The dependent variable is an indicator that takes the value 1 if a household chooses a 5-year contract, and 0 if the household chooses a 2-year contract.[15] The regressors comprise the LTV ratio, the LTV interacted with an indicator variable if the LTV is greater equal 80%, the loan-to-income (LTI) ratio, borrower age (linear and square term), loan term, local house price growth, house price volatility and house price beta, and are converted to standard deviations of the variable.[16] Results are reported in Table 1. Column (1) reports the baseline results, controlling for time (year-month), local-authority×time, lender×time, and borrower-type (first-time buyer, home mover, refinance), loan decile, and sales channel fixed effects (direct/online or intermediated via a broker).

Households who choose a 5-year contract relative to a 2-year contract tend to have a lower LTV, lower mortgage maturity, and somewhat lower local house price growth but also

[15] These account for 87% of all contracts. The excluded contracts have a fixation length of 1 year or less (2% of contracts), 3 to 4 years (7%), and 6 years or more (4%), but results are very similar for an analysis of less than and greater equal 5-year fixed-rate contracts and including these contracts.

[16] Local house price growth is measured as growth two years prior to the choice of contract, local house price volatility is computed as the rolling 10-year volatility in log house price returns, while house price beta is computed as a rolling 10-year beta of local house price returns with respect to aggregate UK house price returns. “Local” refers to a local-authority-level of aggregation which is a typical administrative unit in the UK, with 415 local authorities with an average population of around 200,000, similar to counties in the US.

house price beta. 5-year choice also has an inverse-u-shaped relationship with age, as the linear coefficient on age is positive (but statistically indistinguishable from zero), but the squared coefficient is negative.

LTV seems to be the most important predictor of cross-sectional choice in the data, particularly at high levels of LTV. For a borrower with an LTV greater than 80%, a one standard deviation increase in LTV (around 10 percentage points) reduces the probability of choosing a 5-year fixed-rate contract by around 18%, a large effect. The results hold in each time period or controlling for year-month fixed effects, meaning that high-LTV borrowers are less likely to choose 5-year fixed-rate contracts relative to low-LTV borrowers at any given point in time, which could proxy for time-varying expectations of the path of future interest rates.

While LTV could be correlated with the degree of household financial constraints, the effect of the loan-to-income ratio, a more direct measure of the life-time borrowing and monthly payment constraint, goes to zero when controlling for high levels of LTV. Another way to illustrate the importance of LTV is to compare the adjusted R^2 for univariate predictive regressions of contract choice, reported in online appendix Figure A.3, with LTV having the highest univariate adjusted R^2. The overall adjusted R^2 for the choice regressions is between 0.14 and 0.15, which is moderate but large compared to existing analysis on mortgage choice (see e.g. Cocco (2013)).

The regression also controls for lender×time fixed effects, which captures lender-specific supply shocks. In the mortgage market, loans are written over the full loan term, typically around 30 years, so households face less of a risk of having to roll over their loan which could involve lender-specific risks (Acharya et al., 2011; He and Xiong, 2012; Choi et al., 2018), but rather household-specific repricing risk.

The results also suggest ambiguous ex ante selection patterns. While households who choose a 5-year fixed-rate contract experience slightly lower house price growth, which could be a measure of lower expected house price growth in the future, other ex ante measure of risk such as local house price volatility and local house price beta prior to contract choice are insignificant or even negative. The predictive effect of local house price growth on contract choice is also relatively small, as reported in Figure A.3. Ex post measures of risk such as realized LTV and default are studied further below.

Zooming in on LTV bands, Figure A.4 shows the coefficient of LTV band on 5-year fixed-rate contract choice, with all other covariates partialled out.[17] At an LTV of 70% or lower, contract choice is roughly split, with 58% of borrowers choosing a 2-year contract, and 42% of borrowers choosing a contract with a fixation period of 5 years. The 5-year contract share decreases consistently across LTV bands, with only 18% of borrowers at an LTV of 90-95%

[17] The pattern in the raw data is very similar and reported in online appendix figure A.4.

choosing a 5-year fixation window, with the raw numbers corresponding to 44% and 16%, respectively. A borrower at 95% LTV is thus around two to three times less likely to take out a 5-year fixed-rate contract, compared to a borrower at 70% LTV.

A concern may be that the relationship between LTV and contract choice is driven by an unobserved variable that determines both the choice of fixation length, and household LTV, such as variation in risk aversion. Less risk-averse households may have greater LTV ratios, and less demand for insurance against repricing via 5-year fixed-rate contracts. I can use the panel of first-time borrowers to study the effect in repeated contract choice. Table A.2 reports the linear probability analysis, focusing on the effect of LTV. The coefficients on LTV and LTV interacted with an indicator for an LTV greater equal to 80% are similar, but a bit smaller than in the full origination data.[18] Column 2 estimates the specification with borrower fixed effects, meaning that identification comes from changes in LTV between repeat choices, differencing out any borrower-specific time-invariant unobservable factors. Column 3 conditions on the set of households for which the first choice of fixation length is 2 years, and measures the effect of LTV changes on subsequent choices. Both specifications suggest that an increase in LTV significantly reduces 5-year contract choice probabilities for high-LTV borrowers.

Another potentially unobserved variable is future income growth. Using UK survey data Cocco (2013) finds that future income growth is most closely correlated with the current loan-to-income ratio, which I can control for. In addition, Cloyne et al. (2019) use a longer panel of repeat refinancers in the UK and show that realized income growth for these borrowers is not correlated with fixation length choice.

Lastly, there is limited evidence that the effect of LTV on contract choice is driven by selective supply by lenders or steering. I can split the sample by sales channel, whether the mortgage was sold directly or via a broker, and the decreasing pattern in 5-year fixed-rate choice across the LTV distribution persists in both. Market concentration as measured by a Herfindahl-Hirschman index is similar across fixation length and within a given LTV band. And regulatory queries confirm that there is no variation in the menu of fixation lengths that borrowers can choose from within a given LTV band.

Finding 1: The probability of choosing a 5-year, relative to a 2-year fixed-rate mortgage contract is decreasing in LTV. This is robust to controlling for a range of other variables including the loan-to-income ratio, loan size, loan term and sales channel.

[18] This could be due to the fact that the indicator captures an initial LTV of greater equal to 80%, and so subsequent contract choices are done at lower levels of LTV. In addition, current LTV is reported at origination, but is a derived variable for repeat choices and so may attenuate coefficient values, as loan balances are reported in the panel data, but house prices are based on local house price changes.

3.2. Mortgage Pricing

Why does LTV matter for fixation length choice? In the UK, LTV determines the credit spread that is locked in as part of the mortgage rate, and is also the main pricing measure for credit risk.[19]

Mortgage rates are increasing and convex in LTV bands. Figure 2 illustrates the pricing of LTV by showing the credit spread paid on 5-year fixed-rate mortgages across loan-to-value (LTV) bands, extracted as LTV-band fixed effects from a regression of interest rates on LTV bands, controlling for year-month, lender, buyer-type, year-month×lender fixed effects and fixation length.[20] Below the lower LTV threshold of 70% LTV, interest rates typically do not vary with changes in LTV, which I refer to as the "collateral-insensitive" pricing region. Starting from an LTV of 70% LTV, mortgage rates become increasingly sensitive to the level of LTV and rise in LTV bands of 5 percentage points, up to the highest LTV band of 90-95% LTV, above which very few mortgages are originated and households pay the revert rate. The region between 70% to 95% LTV can be thought of as the "collateral-sensitive" mortgage pricing region. The LTV credit spread is sizeable, and reaches on average 220 basis points for a borrower at 95% LTV, compared to a borrower at 70% LTV over the sample period. Importantly, these credit spreads in an exercise for 2-year fixed-rate contracts are very similar (reported in the online appendix), meaning that households essentially lock in the LTV credit spread at contract origination, regardless of the subsequent fixation length.

3.3. Credit Repricing And The Life Cycle of Credit Risk in Mortgages

Long-term contracts protect against repricing in general, including along the credit dimension. The risk of credit repricing has been studied in the corporate finance literature. Merton (1974) shows that firms who are already very risky may have a higher chance to improve their credit risk rather than deteriorate further over time.[21] The empirical findings are more ambiguous. Sarig and Warga (1989) and Fons (1994) show that credit spreads of riskier firms decrease over time, while Helwege and Turner (1999) show that they increase over time. In comparison, a residential mortgage loan to households is a specific type of collateralized loan, with the value of the house serving as collateral that can be seized in case of default, and full loan repayment over

[19] To illustrate the main drivers of cross-sectional variation in UK mortgage rates, I regress observed mortgage rates on a range of fixed effects, including time, lender, buyer type, fixation length, and all interaction effects. Figure A.2 in the online appendix reports the adjusted R^2 values from these regressions. When comparing the inclusion of different household covariates, the marginal increase in R^2 is highest when including the LTV band fixed effects, with the adjusted R^2 rising from about 55% to around 85%, while the inclusion of income and age deciles only leads to an increase of a few percentage points, consistent with earlier analysis by Benetton (2021); Robles-Garcia (2020), who also confirms that mortgage rates do not differ across FICO scores. FICO scores are only used as a minimum threshold for loan approval, in contrast to the US market setting.

[20] Raw averages of mortgage rates across LTV bands yield very similar results.

[21] This prediction does not extend to firms with greater leverage, however.

time. This implies that there is a downward trend in the measure of credit risk, the LTV ratio, as the loan balance, the numerator, decreases, and the value of the house, the denominator, increases with some positive house price growth. A mortgage loan hence becomes typically less risky over time from the perspective of the lender.

I find evidence for this life-cycle dimension of credit risk in LTV ratios and mortgage rates in the data. Figure 3 shows LTV ratios (Panel A and C) and mortgage rates (Panel B and D) for different cohorts of first-time borrowers (between 2013 and 2015), tracking their outcomes over time, between 2015 to 2017. Panel A illustrates the average decline in LTV for borrowers who start with an LTV of 75%, who reduce their LTV by around 10 percentage points over two years. Since mortgage rates are virtually collateral-insensitive below a threshold of 70%, there is only a small associated decrease in credit spreads and interest rates, as shown in Panel A. In contrast, for borrowers who start with an LTV of 90%, the same percentage point reduction in LTV (Panel C) is associated with large decreases in credit spreads and mortgage rates (Panel D), as LTV changes in the collateral-sensitive pricing region.[22] While each cohort captures different aggregate interest rate levels, there is a significant reduction in credit spreads for each cohort after two years, as many borrowers refinance at that point.

The data reflect one particular realized house price path, with relatively strong house price growth of 4-5% per annum over the sample period, and so provides an ex post view of realized credit repricing. In order to get an ex ante measure of risk which is relevant for household insurance choices, I can also simulate the distribution of LTV and credit spreads using a baseline calibration for house prices. As described in more detail in the model calibration, I calibrate a house price process with average house price growth $\mu_h = 0.0258$ and standard deviation $\sigma_h = 0.077$. The distribution of LTV and credit spreads over time is shown in Figure 4, for simulated households with a starting LTV of 90%. While there is some upward repricing risk with LTV increasing above 90%, there is a strong downward trend such that the probability of upward repricing is less than 5% after 10 years, and the median household is in the collateral-insensitive pricing region below 70% LTV after approximately 7 years. Note that I can also simulate alternative house price scenarios and loan repayment patterns. With lower house price growth and higher house price volatility, the risk that credit spreads rise is more material, and I can evaluate these alternative scenarios as part of the model analysis in section 4.

Finding 2a: There is a life-cycle dimension of credit risk in the mortgage market. Under a baseline calibration with 2.6% annual house price growth and typical loan repayment, the median household who started with a 90% LTV at origination reaches an LTV below 70% after

[22] These findings are consistent across the LTV distribution.

approximately 7 years. House price growth, house price volatility and loan repayment determine credit repricing risk in the mortgage market.

3.4. Credit Repricing And The Relative Cost of Long-Term Mortgages

The expected decrease in credit risk over the life of the mortgage affects the relative cost of longer-term mortgages. I show that the relative cost can be written as the expected yield difference between the longer-term mortgage and sequence of shorter-term contracts, and can be decomposed into two parts (which is summarized here, and outlined in more detail in the online appendix section D): a standard bond term premium, and a premium arising from the expected credit repricing benefit of shorter-term contracts. Intuitively, the latter can be interpreted as an additional term premium in the credit dimension, in this case the initial LTV level, which raises the cost of longer-term mortgage contracts for riskier borrowers, over and above the bond term premium.

The decomposition can be thought of as an extension of the expectations hypothesis of the term structure (Campbell and Shiller, 1991) for mortgage rates, which depend on LTV, in addition to aggregate interest rates. Under the assumption that mortgages with an LTV below the lower pricing threshold are essentially credit-risk free, the expected mortgage yield difference measured at the lowest LTV band of 70% reflects the standard bond term premium. In the data, I indeed find that this measure tracks the funding cost spread between longer and shorter maturity interest swap rates.

The benefit of credit repricing implies that there is an additional term premium over and above the bond term premium from the perspective of the borrower, for mortgages with an LTV above 70%.[23] With expected loan repayment and positive house price growth, there is an expected trend decline in LTV, as the numerator decreases, and the denominator, the house value, appreciates over time. For higher-LTV mortgages, this means that the shorter-term contract sequence reflects an expected decline in mortgage rates with LTV repricing.

I can estimate the effect using an assumption for house price growth. I compute the expected short-term rate path with LTV repricing every two years, given calibrated expected house price growth of 2.6 percent per annum. To offset the decreasing expected short-term rate path over time, the rate on a 5-year 95% LTV contract held over 5 years would have to be 69 basis points lower than the 2-year rate at 95% LTV, respectively. Translating this into a total cost measure for a representative household, inclusive of bond term premia and refinancing cost, observed prices imply that high-LTV borrowers (with an LTV greater than 80%) expect to pay

[23] There could also be a pure pricing difference which I discuss further in the appendix, e.g. the 5-year 80% LTV mortgage rate could be higher than the 2-year 80% LTV rate.

between 8 to 13 percent more for a 5-year contract, compared to taking out a sequence of 2-year contracts. This number is only 4 percent for borrowers with an LTV of 70% or less.

Finding 2b: The downward-trending life-cycle profile of credit risk raises the relative cost of a long-term, compared to a sequence of shorter-term mortgage contracts from the perspective of the borrower.

3.5. Discussion of Mechanisms

This subsection discusses why the cost of a longer-term mortgage contract compared to a sequence of shorter-term mortgage contracts could be increasing in LTV. I proposes a novel explanation based on the systematic nature of house price risks reflected in LTV. There is less direct evidence for information and contracting frictions.

Pricing of House Price Growth. The relative cost of the longer-term contract is more sensitive to the rate of expected house price growth at higher LTV bands. In order to make longer-term contracts attractive to high-LTV borrowers, lenders would have to price in a forward-looking LTV path, and implicitly bear risk of future house price developments over the fixation horizon of the longer-term contract. The findings may be consistent with the lack of financial instruments available to hedge house price risk as observed by Shiller (2014) and Fabozzi et al. (2020), and lenders requiring compensation for exposure to house price risk as a systematic source of risk.

Selection and Screening. Borrowers may strategically select into longer-term contracts if they have private information about future repricing risks, and those with worse future risks may adversely select into longer-term contracts. Lenders may charge a premium on 5-year contracts to screen for that type of selection. In order to test this channel, I evaluate both ex ante and ex post measures of borrower risk. Reviewing the covariates that correlate with 5-year contract choice in the choice regressions in Table 1 suggest that there is limited adverse selection into longer-term contracts based on ex ante observables. Local house price beta as a measure of local house price risk is slightly negatively correlated with 5-year contract take-up.

As a measure of realized risk, I assess ex post default rates that I track in the borrower panel data. Ex post default rates over the sample period are fairly similar across contract types conditional on a given LTV band, shown in Figure A.5.[24] If anything, 2-year borrowers at

[24] There is evidence of "ex post" selection, i.e. 2-year borrowers who leave a lender's borrower pool after 2 years and refinance to a different lender are less than half as likely to default compared to the borrowers who stay (Panel B).

higher LTV who stay with their lender have a slightly higher ex post default probability compared to 5-year borrowers.[25] The share of borrowers who stay should receive a larger weight in the lender's profit function, and so this channel does not help explain the pricing for 5-year high-LTV contracts, but rather exacerbates the discrepancy, with the caveat that the sample window reflects a time period with relatively stable house price growth and low overall rates of default. The finding is consistent with the intuition that one would expect less asymmetric information in a market where the main measure of credit risk is the value of house price collateral, which is considered largely observable due to observable changes in local house price indices.[26] This is in contrast to unsecured credit markets where information asymmetries have been shown to affect contract maturity choice (see e.g., Hertzberg et al., 2018).

Selective Early Prepayment and Adverse Retention. Another canonical long-term contracting problem is selective household attrition over time (Hendel and Lizzeri, 2003; Handel et al., 2015; Nelson, 2018): households who receive better shocks ex post can leave the borrower pool over time, such that lenders retain an adversely selected pool, potentially leading to market unravelling à la Akerlof (1970) in a dynamic sense. 5-year fixed-rate contracts could price in this adverse retention relative to 2-year contracts, and this effect may be more pronounced at higher LTV. In contrast, I find that attrition is limited over the initial fixation window, likely due to significant prepayment penalties. Mortgages in the UK have prepayment penalties of about 3 to 5% of the loan value. More detail on household refinancing behavior is provided in the online appendix.

3.5.1. Summary and Motivation for Model

So far, the analysis has established that the cost of insurance when taking out a 5-year fixed-rate contract is increasing in LTV due the downward-trending life-cycle profile of credit risk. In order to evaluate household contract choices quantitatively, and order to assess the *net* benefit of longer-term contracts to households given cost and the joint distribution and evolution of risks, I develop a model of optimal mortgage fixation choice in the following section.

[25] It is useful to note that ex post default outcomes reflect net selection effects: other factors that affect contract choice, such as financial constraints, could be positively correlated with default, inducing "advantageous" selection into 5-year contracts that may offset adverse selection incentives. Lenders could also use historical data to price default that differs from current default rates.

[26] UK lenders in fact use changes in local house prices to re-evaluate collateral values for refinances with existing customers, without new credit or affordability checks (see FCA Mortgage Market Study, Interim Report 2018).

4. Life-Cycle Model of Optimal Mortgage Fixation Choice

In this section, I develop a partial equilibrium life-cycle model of household consumption and mortgage contract choice. The model allows me to evaluate the net insurance benefit of longer-term contracts, taking into account realistic features of the household choice problem such as income, interest and house price risk, and how these risks evolve over the life cycle. The model features household choice of interest rate fixation length over the life of the loan, and subsequent repricing based on realized loan-to-value ratios and aggregate interest rates, as an extension to existing models of optimal mortgage choice. The model matches the mortgage contract structure in the UK which is common in many countries. It hence differs from influential work by Campbell and Cocco (2003), who evaluate mortgage choice in the US market context with 30-year fixed-rate and adjustable rate mortgages that are held over the life of the loan, with the option to refinance, by introducing frequent repricing and allowing for contract choice across two fixed-rate periods throughout the life of the loan.

4.1. Model Setup

Overview. In the model, households optimally choose consumption and mortgage contracts given two different fixation periods until the loan is repaid, and only consumption thereafter. Households have a finite time horizon, with a working life, after which they retire and die. For simplicity, I focus on homeowners, and assume the size of the house is fixed.[27] Households buy the house at the beginning of their working life with a mortgage and repay it over the maturity of the loan T. Mortgage rates depend on the relative value between the outstanding loan balance and the value of the house price as collateral, i.e. the loan-to-value (LTV) ratio, and the aggregate interest rate (r), at the time when the loan was last repriced. Since the utility derived from the house is fixed, it can be omitted from the household optimization problem.[28]

Utility. Households maximize expected utility with time discount rate δ and discount factor $\beta = \frac{1}{1+\delta}$. Households have constant relative risk aversion (CRRA) utility over consumption:

$$U(C) = \frac{C^{1-\gamma} - 1}{1 - \gamma} \tag{1}$$

Dynamic Budget Constraint. Households face idiosyncratic income risk. At each time period, households pay mortgage payment $M_t = L_t \cdot \frac{r_t^m}{1-(1+r_t^m)^{-T}}$, where L_t is the remaining loan balance

[27] The model does not endogenize the decision to buy a house or rent, and the choice of the size of the house, which is assumed to be fixed. Hence households are assumed to strictly prefer buying a house to renting and cannot adjust their house size in response to shocks, as in Campbell and Cocco (2003).

[28] This assumption is justified when households have separable utility between housing and consumption (Campbell and Cocco, 2003) or CES utility with a unitary elasticity of substitution (Laibson et al., 2021).

outstanding at time t. The mortgage interest rate r_t^m depends on the aggregate interest rate r_t^τ plus a time-invariant premium over the base rate ρ^m, which compensates the lender for the cost of issuing a given loan independent of LTV, and the LTV ratio LTV_t^τ locked in at the last instance of repricing (at time $t = \tau$), tracked in superscript:

$$r_t^m = \rho^m + r_t^\tau + f(LTV_t^\tau, \theta^\tau).$$

$f(\cdot)$ is the lender credit pricing function which is increasing and convex in LTV, and which may differ across contract fixation length θ. This component can be thought of as the credit spread for a given level of LTV. The LTV ratio at time t is determined by the outstanding loan value L_t relative to the current value of the house:

$$LTV_t = \frac{L_t}{H_t}$$

House prices H_t follow a lognormal distribution, and the change in log house prices is given by

$$\Delta \log H_t = g + \eta_t \tag{2}$$

with constant g and an i.i.d normally distributed shock with mean zero and variance σ_η^2. The expected log real return on a one-period bond $r_t = \log(1 + R_t)$ follows an AR(1) process:

$$r_t = (1 - \rho_r)\mu_r + \rho_r r_{t-1} + \xi_t, \tag{3}$$

where ξ_t is a normally distributed white noise shock with mean zero and variance σ_ξ^2. Household net wealth X_t evolves according to the following dynamic budget constraint:

$$X_{t+1} = (1 + r_t)(X_t - C_t) - M_t(LTV_t^\tau, r_t^\tau) + Y_{t+1},$$

subject to the borrowing constraint $(1 + r_t)(X_t - C_t) - M_t \geq \bar{B}$.[29] Next period net wealth is net savings compensated at the risk-free rate, less mortgage payments, plus income. Log income $\ln(Y_t)$ has a deterministic component $f(t)$ that is a function of time t, and is subject to transitory shocks ϵ_t. ϵ_t is an i.i.d normal shock with mean 0 and standard deviation σ_ϵ.[30]

[29]The model abstracts from the ability to extract home equity, and housing wealth does not enter household utility directly. This would introduce additional variation in the cost of borrowing across the LTV distribution, as this would be captured in the mortgage rate that is increasing in LTV. This also leaves out an additional benefit of shorter-term mortgage rates, as they may give borrowers greater flexibility to cash out at shorter time intervals (given costly prepayment penalties over the initial fixation period).

[30]Income shocks are assumed to be i.i.d in order to simplify the problem and economize on state variables.

Mortgage Contract Choice. Households choose the fixation length θ over which they lock in the current mortgage rate, and hence the point in time at which they get repriced next, i.e. θ periods from when the contract is chosen. A longer θ exposes household less frequently to repricing risk, but overall house price and aggregate interest rate changes accrue over the repricing window and are repriced at the end of the repricing window. Since house price shocks are i.i.d., multi-period house price risk over the duration of the fixation period can be expressed with mean and variance:

$$E\left(\eta_{t,t+\theta}\right) = E\left(\sum_{i=1}^{\theta} \eta_{t+i,t+i-1}\right) = \sum_{i=1}^{\theta} E\left(\eta_{t+i,t+i-1}\right) = \theta\mu_h$$
$$\text{Var}\left(\eta_{t,t+\theta}\right) = \text{Var}\left(\sum_{i=1}^{\theta} \eta_{t+i,t+i-1}\right) = \sum_{i=1}^{\theta} \text{Var}\left(\eta_{t+i,t+i-1}\right) = \theta\sigma_h^2.$$

In the baseline model, mortgages are assumed to be fully amortizing, i.e. households repay both capital and interest over the life of the loan, and so the loan value L_t decreases over time, i.e. $\Delta L_{t,t+\theta} \leq 0$. Households can choose between a relatively longer-term fixation period θ^{LT}, and relatively shorter-term fixation period θ^{ST}. Once they make a choice, the mortgage rate is locked in over the fixation length chosen, and a new contract can be chosen at the end of the fixation period. In order to economize on state variables, the model assumes that the loan balance can be tracked using time t alone.[31] The model tracks LTV as a state variable, which is then sufficient to track the house price evolution over time.[32]

Value Function and Repricing States. In order to determine optimal mortgage choice (stored in policy function $\mathcal{R}$), the household value function tracks two auxiliary value functions, the value function if the household chooses the short-term contract V^{ST}, which implies repricing in θ^{ST} periods, and new choice of fixation length at the end of the current fixation period; and the value function if the long-term contract is chosen, V^{LT}, with repricing and new choice in θ^{LT} periods. Both take into account that the current rate is locked in and repriced at the end of the chosen fixation window. Rather than tracking the time at which repricing next takes place (τ), repricing depending on contract choice is tracked more parsimoniously by repricing state variables $\mathcal{S}_t^{\theta}$ which take θ states defined as follows: for each fixation window, interest rates are locked in at a given LTV level for θ periods ($\mathcal{S}_t^{\theta} = \theta$), locked in for $\theta - 1$ periods ($\mathcal{S}_t^{\theta} = \theta - 1$), up

[31] This is a common and quantitatively small approximation that abstracts from small variations in the loan amortization path due to differences in interest rates (Campbell and Cocco, 2003, 2015).

[32] The model abstracts from an explicit strategic default decision given the full recourse regime of the UK. Default behaviour is implicitly captured by the household utility maximization problem that avoids states with high mortgage payments (and hence low consumption). In the robustness check with high revert rates, this rate could be considered a penalty rate that serves as a proxy for the expected cost of default, which becomes more likely at an LTV exceeding 95%.

until when the remaining fixation window reaches 1 period, at the end of which there is θ-period repricing ($\mathcal{S}_t^\theta = 1$), for $\theta \in \{\theta^{LT}, \theta^{ST}\}$. V^{LT} and V^{ST} are further defined in the following. The vector of state variables is $\Omega = \{X, t, LTV, r, \mathcal{S}^{\theta^{LT}}, \mathcal{S}^{\theta^{ST}}\}$, representing household net wealth, time, LTV, aggregate interest rate, repricing state for the longer-term contract, and repricing state for the shorter-term contract, respectively. To simplify notation, the θ-superscripts for the repricing state variables are omitted if the information is not required. First, in order to capture the temporal dependence of repricing states for the value function when choosing a contract with fixation window θ, it is useful to note that in θ periods from choosing the contract, the value function is

$$\begin{aligned} &V_{t+\theta-1}\left(X_{t+\theta-1}, LTV_{t+\theta-1}, r_{t+\theta-1}, \mathcal{S}_{t+\theta-1} | \mathcal{S}_{t+\theta-1} = 1\right) \\ &= \underset{C_{t+\theta-1}, R_{t+\theta-1}}{max} U(C_{t+\theta-1}) + \beta E_{t+\theta-1}\left[V^*_{t+\theta}\left(X_{t+\theta}, LTV_{t+\theta}, r_{t+\theta}\right)\right], \end{aligned} \tag{4}$$

with θ-period repricing if $\mathcal{S}_t = 1$, and no repricing if $\mathcal{S}_t \in \{2, ...\theta\}$. Note that the continuation value, where $V_t^* = \max\left\{V_t^{ST}, V_t^{LT}\right\}$, takes into account that the household can optimally choose a short- or long-term contract after this period, and does not depend on the repricing state. In $\theta - 1$ periods, the value function is

$$\begin{aligned} &V_{t+\theta-2}\left(X_{t+\theta-2}, LTV_{t+\theta-2}, r_{t+\theta-2}, \mathcal{S}_{t+\theta-2} | \mathcal{S}_{t+\theta-2} = 2\right) \\ &= \underset{C_{t+\theta-2}, R_{t+\theta-2}}{max} U(C_{t+\theta-2}) \\ &+ \beta E_{t+\theta-2}\left[V^{LT}_{t+\theta-1}\left(X_{t+\theta-1}, LTV_{t+\theta-1}, r_{t+\theta-1}, \mathcal{S}_{t+\theta-1} \mid \mathcal{S}_{t+\theta-1} = 1\right)\right], \end{aligned} \tag{5}$$

which can be extended analogously for each period up until (and including) the current period. In the current period, the value function for choosing the long-term contract is

$$\begin{aligned} &V_t\left(X_t, LTV_t, r_t, \mathcal{S}_t \mid \mathcal{S}_t = \theta\right) \\ &= \underset{C_t, R_t}{max} U(C_t) + \beta E_t\left[V^{LT}_{t+1}\left(X_{t+1}, LTV_{t+1}, r_{t+1}, \mathcal{S}_{t+1} \mid \mathcal{S}_{t+1} = \theta - 1\right)\right]. \end{aligned} \tag{6}$$

For notational simplicity, the value functions for choice of the short-term and long-term contract are respectively defined as

$$\begin{aligned} V_t^{ST} &\equiv V_t\left(X_t, LTV_t, r_t, \mathcal{S}_t^{\theta^{ST}} \mid \mathcal{S}_t^{\theta^{ST}} = \theta^{ST}\right), \\ V_t^{LT} &\equiv V_t\left(X_t, LTV_t, r_t, \mathcal{S}_t^{\theta^{LT}} \mid \mathcal{S}_t^{\theta^{LT}} = \theta^{LT}\right). \end{aligned} \tag{7}$$

The dependencies across time and repricing states are further illustrated for V^{LT} with $\theta^{LT} = 5$ in Figure A.7 in the appendix, with arrows to indicate the dependencies of the value function and continuation values as described above.

The dynamic budget constraint can then be rewritten without τ, and using the repricing state variable instead:

$$X_{t+1} = (1 + r_t)(X_t - C_t) - M_t(LTV_t, r_t, \mathcal{S}_t) + Y_{t+1}. \tag{8}$$

Policy Functions. Households choose optimal consumption and the optimal mortgage contract in the model. Let policy function C denote household optimal consumption in state $\Omega = \{X, t, LTV, r, \mathcal{S}^{\theta^{LT}}, \mathcal{S}^{\theta^{ST}}\}$ where $C : \Omega \to [0, \infty)$, and $\mathcal{R}$ denote optimal mortgage choice of either the long-term ($\mathcal{R} = 1$) or short-term contract ($\mathcal{R} = 2$) where $\mathcal{R} : \Omega \to \{1, 2\}$.

Bellman Equation. The resulting Bellman equation for the household problem is

$$\begin{aligned}
V_t\left(X_t, LTV_t, r_t, \mathcal{S}_t^{\theta^{ST}}, \mathcal{S}_t^{\theta^{LT}}\right) &= \underset{C_t,R_t}{max}\; U(C_t) + \beta E_t\left[V_{t+1}^{*}\left(X_{t+1}, LTV_{t+1}, r_{t+1}\right)\right] \text{ with} \qquad (9)\\
V_t^{*} &= \max\left\{V_t^{ST}, V_t^{LT}\right\}\\
V_t^{ST} &= \underset{C_t,R_t}{max}\; U(C_t) + \beta E_t\left[V_{t+1}^{ST}\left(X_{t+1}, LTV_{t+1}, r_{t+1}, \mathcal{S}_{t+1}^{\theta^{ST}}\right)\right]\\
V_t^{LT} &= \underset{C_t,R_t}{max}\; U(C_t) + \beta E_t\left[V_{t+1}^{LT}\left(X_{t+1}, LTV_{t+1}, r_{t+1}, \mathcal{S}_{t+1}^{\theta^{LT}}\right)\right]\\
\text{s.t.} \quad X_{t+1} &= (1 + r_t)(X_t - C_t) - M_t(LTV_t, r_t, \mathcal{S}_t) + Y_{t+1},\\
(1 + r_t)(X_t - C_t) + M_t &\geq \bar{B}.
\end{aligned}$$

4.2. Calibration and Solution

Table 2 provides an overview of the parameters used for the baseline calibration of the model.

House Prices. The house price process is calibrated using aggregate UK house price from 1987 to 2017, with nominal house prices deflated using RPI, yielding an average log house price growth of 0.0258 and standard deviation $\sigma_h = 0.0770$.[33] The initial house price level is set to fit the average loan-to-income (LTI) ratio of borrowers with an initial LTV of 85% in the data, yielding an LTI ratio of 3.56.[34]

Interest Rate. The real log interest rate is calibrated using UK data from 1987 to 2017, with mean $\mu_r = 0.0164$, standard deviation $\sigma_r = 0.0193$ and autocorrelation coefficient $\rho_r = 0.95$. Real rates are calibrated using 5-year UK inflation-indexed gilts, and cross-checked using 1-year

[33] As an alternative, local authority-level house price indices are used to capture cross-sectional variation in house price risk which yields similar magnitudes.

[34] Because all values are standardized in terms of units of permanent income, the loan-to-after-tax-income ratio of 4.82 is used after applying a tax rate of 35.5%, based on 2017/2018 effective UK tax rates.

nominal rates deflated by 1-year ahead survey-based household expectations of inflation.

Income and Mortgage Contract. Working age is set to 30 to 60, after which households retire and die at age 80. The deterministic hump-shaped component of income over the life cycle is adopted from Cocco et al. (2005), following standard life-cycle models (Carroll, 1997).[35] The standard deviation of the transitory income shock σ_ϵ is set to 0.1 based on the literature.[36] The maturity of the loan T is set to 30 years. The fixation windows that households can choose from are set to 5 (θ^{LT}) and 2 (θ^{ST}) years, respectively, matching the UK institutional setting and the two most common types of contracts available. For some counterfactuals, θ^{LT} is set to 10, reflecting a 10-year fixed-rate contract.

Mortgage Pricing. The mortgage rate premium ρ^m is set to the difference between the average 2-year mortgage rate at an LTV of 60% or lower and the real rate, and uses data between 2013 and 2017 to match the LTV premia derived from the loan-level data. Consistent with the empirical mapping proposed earlier, I use the same credit spreads across LTV in the model calibration, estimated as LTV-band fixed effects in steps of 5 percentage points from 70% to 95% LTV, controlling for time (year-month), lender, region, time×lender and buyer-type fixed effects between 2013 to 2017.[37] The revert rate premium is obtained from the Bank of England database, as the difference between the average revert rate and the average 2-year mortgage rate at an LTV of 60%. Based on this calibration, the real mortgage rate with an aggregate rate of 1% for a 2-year 80% LTV contract is 2.24%, while it is 2.96% for a 2-year 90% LTV, and 4.07% for a 2-year 95% LTV contract.

Summary and Model Solution. To summarize, the household decision problem is tracked using the state variable vector $\Omega = \{X, t, LTV, r, \mathcal{S}^{\theta^{LT}}, \mathcal{S}^{\theta^{ST}}\}$ and contains household net wealth, time/age, LTV, aggregate interest rate, repricing state for the longer-term contract, and repricing state for the shorter-term contract. The model solution is briefly outlined in the following, with more detail provided in appendix section E. The state space is discretized in an equal-spaced grid for the continuous state variables X and LTV, interest rates are discretized using five states, and the model is solved recursively by setting $V_T = C_T$ in the last period, i.e. assuming households consume all wealth in the last period. Household consumption, also discretized,

[35]The deterministic income profile is based on a simple average of households with college education and households with high school education in Cocco et al. (2005), to approximate the population with a mortgage.

[36]See e.g. Blundell (2014); Belgibayeva et al. (2020) for the UK, and Carroll et al. (2017); Gomes (2020) for a more general range of estimates and alternative specifications.

[37]The calibration assumes that the relative differences in interest rate premia across the LTV distribution are preserved in real terms. Collateral term premia would likely be larger if interest rate premia apply to nominal LTV, as nominal LTV may decrease more quickly over time given nominal rather than real house price growth.

and mortgage choice functions are obtained as optimal choices across each combination of the discretized points on the state space using a grid search. The policy functions are then used to simulate consumption and mortgage choice given simulated realizations of income, house price and interest rate shocks for 10,000 households.

4.3. Results

This subsection provides an overview of the main findings from the model. After solving for optimal mortgage fixation choice and simulating household choices, I can vary the choice set to evaluate the marginal welfare benefit of adding a longer-term contract. I find that high-LTV households have a reduced willingness to pay for adding a longer-term contract to their choice set compared to low-LTV borrowers, amounting to 0.5% less in annual consumption for 5-year, and 1.3% less for 10-year fixed-rate contracts. Similarly, optimal mortgage fixation length is decreasing in LTV, in line with the data.

Optimal Mortgage Fixation Policy. To provide intuition on the model results, the following illustrates patterns in the policy function for optimal mortgage fixation choice. Under the baseline calibration and given an intermediate aggregate interest rate state, borrowers prefer the short-term contract (with $\theta^{LT} = 2$) to the long-term contract (with $\theta^{ST} = 5$) whenever the mortgage rate is in the collateral-sensitive pricing region between 70% to 95% LTV. For an LTV below or equal to 70%, the mortgage rate is in the collateral-insensitive pricing region, i.e. there are no further interest rate reductions for an LTV lower than 70%, and the optimal choice is to lock in this rate for longer. Households hence trade off their insurance motive against upward interest rate (and downward house price) risk, and expected cost reductions in credit spreads using shorter-term contracts.

The model can also be solved under different configurations of risk and house price growth, to evaluate how optimal choice depends on the risk environment. In a scenario with no house price growth, and higher interest rate risk ($\sigma_r = 0.0193 \times 2$), households choose long-term contracts at higher levels of LTV, up to 90%, and closer to the initial loan origination date, i.e. within the first 5 to 10 years, as the risk of upward repricing in the credit dimension is largest given larger loan balances. In a scenario with greater interest rate risk, households choose long-term contracts at higher levels of LTV throughout.

Household Valuation of Long-Term Contract. I then quantify the marginal welfare benefit of adding a longer-term contract to the choice set as a standard consumption certainty equivalent. This requires solving the model twice, first under the restriction that households can only choose a short-term contract, and second when households are allowed to choose between the short- and longer-term contract. The consumption certainty equivalent is computed as the percentage increase in consumption across states that a household would require to reach the same lifetime expected utility when a longer-term contract is available. Table 4 shows results from a comparison of consumption certainty equivalents under different scenarios. Each row represents a different scenario, while columns 1 and 2 show results for low (70%) and high (90%) LTV contracts under observed pricing, and columns 3 and 4 show the equivalent under an assumption when the longer-term contract is priced at the expected cost of rolling over the short-term contract sequence ("expected cost pricing").[38] In the baseline calibration, households' marginal benefit of adding a 5-year contract to their choice set is 0.85%, but this declines to 0.36% for households with an LTV of 90% (Panel A).

I can also use the model to evaluate the value of a counterfactual 10-year fixed-rate contract,[39] with results shown in Panel B. The gap in the welfare benefit between low- and high-LTV borrowers is even greater: while the value is 2.03% of lifetime consumption for low-LTV borrowers, this value is only a third, 0.74%, for high-LTV borrowers, a larger proportional decrease compared to the 5-year contract. The intuition is that the opportunity cost of not repricing in the credit dimension over 10 years is even greater than not repricing over 5 years, and so the credit repricing effect is exacerbated at longer fixation lengths.

Finding 3a: High-LTV households have a reduced willingness to pay for 5-year fixed-rate contracts, in addition to 2-year fixed-rate contracts. Under a baseline calibration for income, interest rates and house prices, the marginal insurance value of longer-term contracts is between 0.36% to 0.74% for high-LTV borrowers, around half to a third of that for low-LTV borrowers.

The results in alternative scenarios in the following rows suggest that house price growth plays an important role in both raising the expected credit repricing benefit, as well as reducing repricing risk to the upside. High-LTV borrowers almost reach the same insurance value from longer-term contracts in a scenario without house price growth. In addition, in a scenario with higher interest risk the insurance rises for both low- and high-LTV borrowers, to 1.47% and 1.44%, respectively. The expected cost pricing columns estimate the insurance value if high-LTV households were able to pay the expected cost of rolling over a short-term contract sequence, while taking out the longer term contract, which gives a sense of how valuable it is to

[38]Households' initial LTV level is taken as given, based on the empirical findings that control for other variables such as the LTI ratio and past house price growth which could be a proxy for house price beliefs (Bailey et al., 2019) and finds that the effects on fixation choice are small.

[39]This assumes effective commitment over the initial fixation window under a binding prepayment penalty, and using the credit risk pricing for the 5-year contract.

insure households against both interest rate and credit repricing risk, especially in a more risky environment.

Finding 3b: The insurance value of 5-year fixed-rate contracts only equalizes across low- and high-LTV borrowers when there is no house price growth, and much higher interest rate risk.

Life-Cycle Pattern in Simulated Mortgage Choice. Figure 5 shows the simulated mortgage choices for an initial LTV of 70% (Panel A) and 90% (Panel B) for the baseline calibration. In line with the policy function intuition and results above, borrowers at 70% LTV start off with a 5-year contract, but those who receive negative house price or positive interest rate shocks move onto a short-term contract. Borrowers at 90% LTV start off with a 2-year contract, but the majority of borrowers moves onto a 5-year contract after about seven years, as the LTV reaches the long-term choice boundary at 70%.

Table 3 summarizes long-term contract take-up over the initial first 10 years of the loan (Panel A) and over the entire loan maturity of 30 years (Panel B). Take-up is computed as the share of borrower-year observations under the 5-year fixed-rate contract, relative to the 2-year fixed-rate contract. Long-term contract take-up for low-LTV borrowers is close to 100% throughout. High-LTV take-up under the baseline is about half that of low LTV borrowers, and rises in particular for combinations of no house price growth and higher house price risk (second row), and higher house price and interest rate risk (fifth row).

In the model and simulation, households are homogeneous other than their initial starting LTV. I show that this dimension of heterogeneity alone generates a substantial decrease in 5-year contract take-up.[40] This is consistent with the empirical findings from the multivariate linear probability model of predicting 5-year contract choice – 5-year contract choice is strongly decreasing in LTV, holding fixed measures of financial constraints such as loan-to-income, age and maturity.

Finding 3c: Optimal mortgage fixation length is hence decreasing in LTV, and increasing over the life cycle of the mortgage, as LTV decreases over time, in line with the data.

Robustness and Alternative Scenarios. I can also vary household discount rate and risk aversion parameters, with results shown in Tables A.3 and A.4 in the online appendix. Take-up for high-LTV borrowers compared to the baseline is lower in the scenario with a higher time discount rate, and a higher revert rate, but is unchanged with greater risk aversion, suggesting that the

[40] There is no other source of heterogeneity in the model, which is best interpreted for a representative household, and so contract shares over time arise due to different realized house price, interest rate and income shocks.

cost reduction motive weighs strongly against households' insurance motive. Relative value-added compared to the baseline is lower with a higher revert rate and discount rate. The insurance value is raised with greater risk aversion for low-LTV borrowers, but unchanged for high-LTV borrowers.

4.4. Discussion of Results

The model results confirm that under a realistic scenario for house price, interest rate and income risks, optimal mortgage fixation length is decreasing in LTV, in line with the data. As a result, high-LTV borrowers insure less against interest rate risk compared to low-LTV borrowers. The paper highlights a tension between households' insurance motive, and a cost savings motive, as repricing more frequently allows households to reduce the credit spread while LTV decreases over time. The findings further suggest that the welfare benefits of alternative contract designs, such as allowing high-LTV borrowers to lock in the base rate, but reprice their credit spreads, is potentially large.

This model quantifies potential welfare gains and distributional effects of long-term contract pricing for representative low- and high-LTV borrowers, focusing on how credit repricing affects optimal contract choice throughout the life of the loan. It is hence complementary to models that study optimal mortgage design, contract and house prices in equilibrium, and which emphasize the benefits of state-contingent contract elements (Piskorski and Tchistyi, 2010), such as the option to convert a 30-year fixed-rate mortgage to an adjustable-rate mortgage which can enhance the stabilizing effects of monetary policy in downturns (Guren et al., 2021; Campbell et al., 2021), or indexing mortgage payments to house prices (Greenwald et al., 2021). The quantification of household willingness-to-pay for long-term contracts follows approaches in the public finance and insurance literatures (Brown and Finkelstein, 2008; Hosseini, 2015) to estimate counterfactual demand for non-traded or missing markets and help explain the lack of longer mortgage fixation lengths in the market.

Long-term contracting can be difficult to sustain due to a number of market imperfections. In the mortgage market, key dimensions of risk are systematic. This paper highlights the role of the loan-to-value ratio as a measure of collateralization and important determinant of mortgage credit spreads. The first-order mechanism that I uncover is that lenders would have to price in a forward-looking path of collateral, and hence provide insurance against house price risk, in order to make long-term contracts attractive to high-LTV borrowers who pay high credit spreads. If households have private information about their future repricing risks, this may further impede long-term contracting.

From a policy perspective, one way to sustain long-term contracts is government insurance of house price risk, as seen in the US market. Centralized pricing by government-sponsored entities has been shown to have regionally redistributive effects (Hurst et al., 2016). A flattening of the LTV pricing curve for longer-term contracts could be interpreted as an additional dimension of redistribution: cross-subsidization from low to high-LTV borrowers, or younger and older cohorts of borrowers, as the credit spread is spread out over time and across LTV groups.[41] Of course, the unintended cost of government insurance of house price risk and securitization could involve an increase in moral hazard and systemic risk (Acharya et al., 2009; Keys et al., 2010; Allen et al., 2015; Bhutta and Keys, 2022). The paper hence highlights novel considerations and challenges for mortgage contract design and market reform.

The paper findings are consistent with cross-country evidence of mortgage fixation lengths being relatively short, and the US 30-year fixed-rate mortgage being an exception. Figure A.6 in the online appendix shows average fixation lengths across a range of advanced economies. The average fixation period is around 2 to 2.5 years in the UK, Greece and Spain, around five years in the Netherlands and Italy, around ten years in Denmark and Germany.[42] The right-hand axis also plots a measure of average household indebtedness relative to average house price levels. Household indebtedness is somewhat negatively correlated with average mortgage fixation length, and the US has similar levels of indebtedness, but much longer average fixation lengths of 25 years, suggesting that this outcome may be sustained by policy interventions in the mortgage market, and may not arise in markets without public credit risk guarantees.

5. Conclusion

This paper studies household mortgage fixation choice in a setting with frequent repricing and market pricing of credit risk, the UK mortgage market. It documents a life-cycle dimension of credit risk in the mortgage market: over the life of the loan, the loan-to-value ratio typically declines and thus collateral coverage improves, due to principal repayment and house price appreciation. When considering a longer fixation length, high-LTV borrowers face a trade-off between their regular demand to insure against repricing, and obtaining a lower credit spread over time by repricing more frequently, lowering the expected cost of the shorter-term contract sequence.

[41] An alternative policy could be repricing credit spreads, while locking in the base rate, as seen in the Netherlands, or structuring mortgages into a non-risky, i.e. LTV-insensitive, tranche, and a risky tranche, as done in Denmark, where collateralized mortgage loans are only available up to an LTV of 80%. Borrowers can then borrow an unsecured loan to raise their LTV up to 95%. This way, base rates can be locked in at origination, while the risky portion of the loan can be repaid separately. One disadvantage is that these unsecured loans are potentially quite expensive.

[42] The data is taken from Badarinza et al. (2016), which does not include averages for Canada and Australia, so the most common range of products is shown, which is between 2 and 5 years.

The paper further proposes a model of optimal mortgage fixation choice. I use the model to evaluate the marginal insurance benefit of longer-term contracts by varying households' available contract choice sets. I find that high-LTV households have a reduced willingness to pay for 5-year fixed-rate contracts, in addition to 2-year fixed-rate contracts, suggesting that the insurance benefits of longer-term contracts are unequally distributed across households due to credit risk. A baseline calibration of risks is not sufficient to generate demand for 5-year fixed-rate contracts for high-LTV borrowers. The model helps explain the missing, or very small, markets for even longer-term contracts such as 10-year fixed-rate contracts in the UK, and the prevalence of relatively short mortgage fixation lengths across most countries.

The paper proposes a mechanism that reduces pooling and hence risk-sharing in longer-term contracts in high-LTV segments of the mortgage market. The lack of long-term contract take-up in the mortgage market was noted by Miles (2004) in a comprehensive review of the UK mortgage market commissioned by the UK government. In the US mortgage market context, mortgage contracts have historically evolved from short-term balloon-mortgages with substantial repricing risk in the 1930s, to the institutional framework surrounding the 30-year fixed-rate mortgage today (Green and Wachter, 2005). This has remained a subject of on-going discussion on mortgage market reform (Campbell, 2013) given the large public cost externalities posed by public credit risk guarantees following the 2008/09 financial crisis. One way to interpret the role of public credit risk guarantees is that they may redistribute high initial credit spreads due to LTV from high to low LTV borrowers and over a longer-term contracting horizon, flattening the LTV pricing curve and thereby lowering the cost of insurance against interest rate risk for high-LTV borrowers. Without such pooled credit risk pricing, market pricing incentivizes higher-LTV borrowers towards shorter-term contracts, rendering the combination of high-LTV borrowing and long-term contracting particularly challenging, and may help explain continued government interventions observed in mortgage markets.

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Figure 1: Fixation Length Contract Choice by LTV

This figure shows the residualized probability of choosing a 5-year fixed-rate contract across LTV bands, by regressing an indicator variable that takes the value 1 if households chooce a 5-year fixed-rate contract, and 0 if households choose a 2-year fixed-rate contract on LTV band indicators, with the effect of covariates (LTI ratio, age, age squared, loan term) and time (year-month), local authority, time×local authority, lender, lender×local authority, borrower type, loan deciles, and sales channel (intermediated or direct sale) fixed effects partialled out. The LTV-band coefficients are added to the base category (LTV$\leq$ 70%) level. Standard errors are clustered at the local authority- and year-month level. The non-residualized raw probabilities are reported in online appendix Figure A.4.

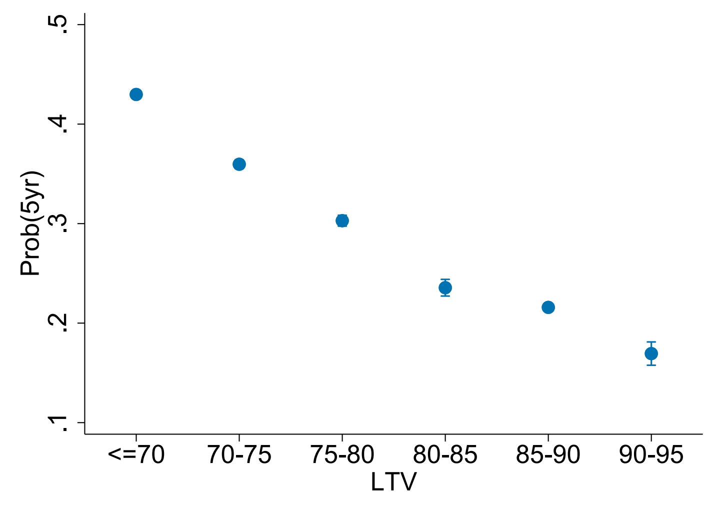


Figure 2: LTV Pricing

This figure plots the credit spread paid on 5-year fixed-rate mortgages across loan-to-value (LTV) bands ($\leq$70%, (70-75]%, (75-80]%, (80-85]%, (85-90]%, and (90-95]%), by extracting LTV-band fixed effects from a regression of interest rates on LTV bands and fixation length, controlling for year-month, lender, buyer-type, year-month×lender fixed effects, using data from 2013 to 2017. The fixed-effect point estimates are plotted as LTV band levels, with confidence bands based on standard errors clustered by time and lender.

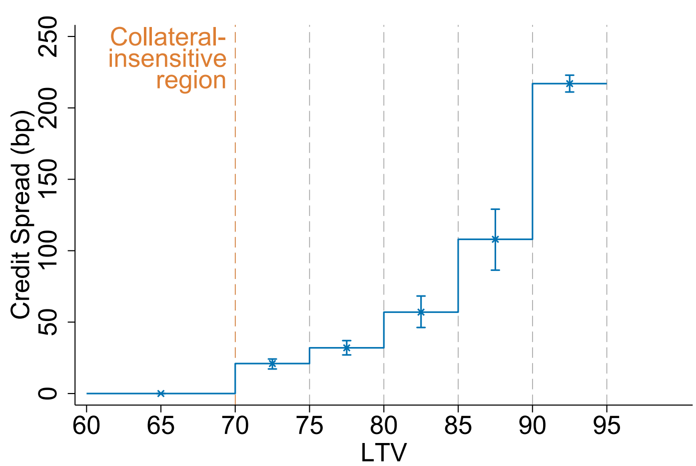
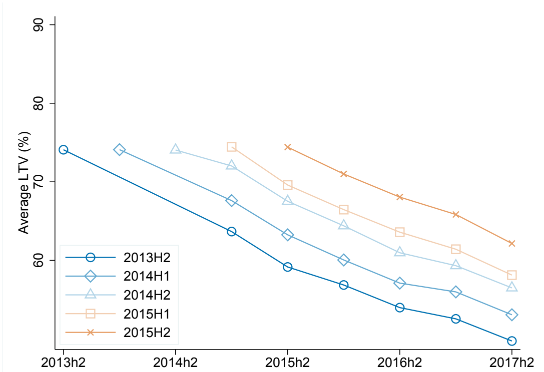


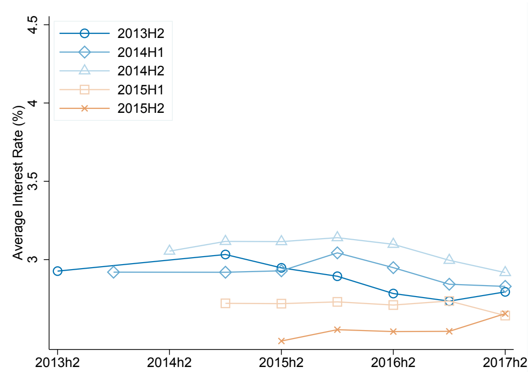
Figure 3: LTV and Interest Rates Over the Life Cycle, by Cohort

This figure shows the average loan-to-value (LTV) ratio and mortgage interest rates for different first-time borrower cohorts (originating their loans between 2013H2 and 2015H2), tracked over time at half-yearly frequency using the borrower panel data between 2015H1 to 2017H2. The current LTV ratio is computed as the reported current loan balance, divided by the current house price, obtained by scaling the initial house price with the local-authority-specific house price index. The current mortgage rate is directly reported in the panel data. Panel (A) and (C) show cohorts of borrowers that originated with an initial LTV between 85 to 90%, Panel (B) and (D) show cohorts of borrowers with an initial LTV between 70 and 75% LTV.

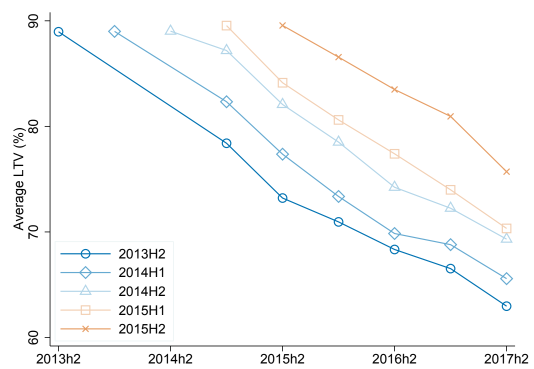
(a) LTV (75%)



(b) Mortgage Rate (75% LTV)



(c) LTV (90%)



(d) Mortgage Rate (90% LTV)

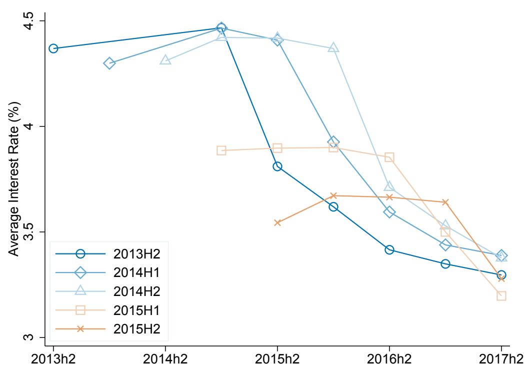
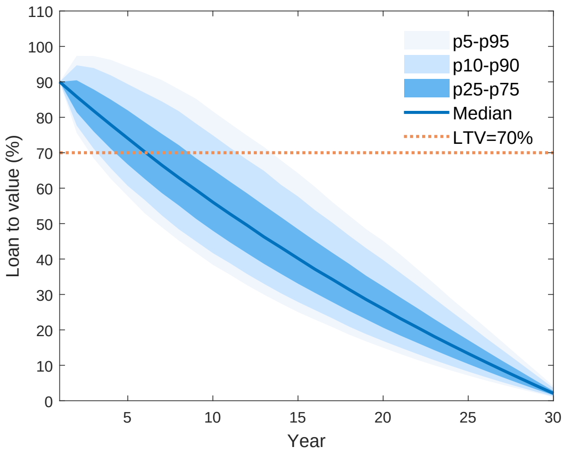


Figure 4: Simulation

These figures illustrate the distribution of repricing risks over the life of the loan. The simulation is based on a fully-amortizing loan, repaid over 30 years, using LTV pricing estimated from the data, and a calibrated house price and interest rate process as shown in Table 2. Panel A shows the distribution of LTV, Panel B shows the mortgage rate distribution with house price risk but no interest rate risk, while Panel C shows the mortgage rate distribution with both house price risk and interest rate risk, for a loan with an initial 90% LTV. The dark blue line indicates the median (50th percentile) of the distribution, the dark blue swathe indicates the interquartile range (25th to 75th percentile), the light blue swathe indicates the interdecile range (10th to 90th percentile), and the grey swathe the 5th to 95th percentile range. The dotted orange line indicates the LTV pricing boundary at 70% LTV, and the interest rate associated with the LTV pricing boundary, respectively.

(a) Simulated LTV (90%)



(b) Simulated LTV Credit Spread (90%)

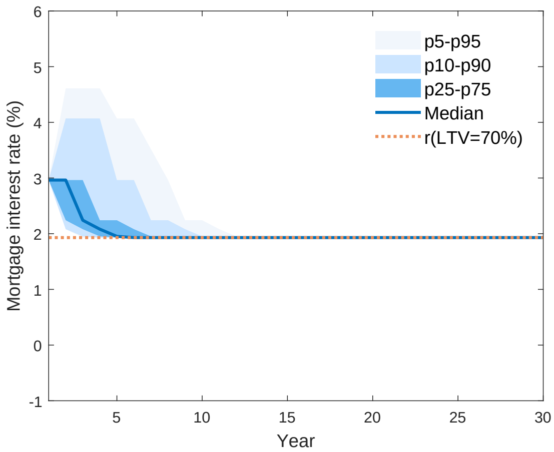
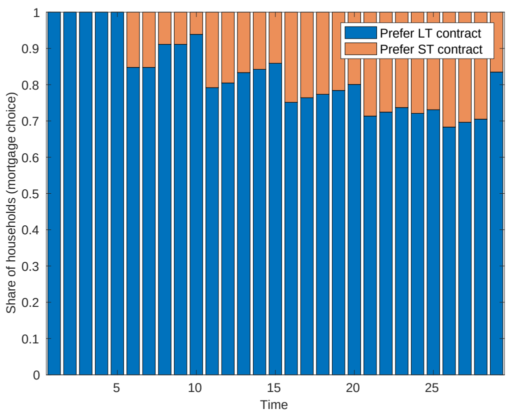


Figure 5: Optimal Mortgage Choice Over the Life of the Loan

These figures show simulated optimal mortgage choice for a relatively long-term contract with fixation length $\theta^{LT} = 5$ against a shorter-term contract with $\theta^{ST} = 2$, under the baseline calibration for households with an initial LTV of 70% (Panel A) and 90% (Panel B), and for households with an initial LTV of 90% for the baseline calibration.

(a) Low LTV (Baseline)



(b) High LTV (Baseline)

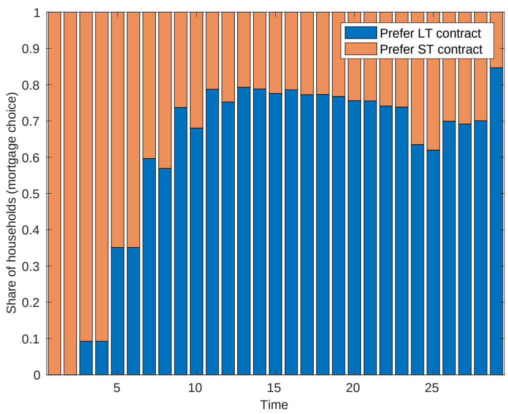


Table 1: 5-year Contract Choice Regressions

This table shows three regressions of the probability of taking out a 5-year contract, compared to taking out a 2-year contract, on a set of covariates that could be related to 5-year contract choice. The dependent variable is an indicator that takes the value 1 if the contract fixation length is 5 years, and 0 if the fixation length is 2 years. All independent variables are expressed in standard deviations of the variable. Column (1) uses past (10-year) local quarterly house price volatility, while column (2) uses a rolling (10-year) beta of the local house price index with respect to the aggregate house price index. Column (3) instead includes local-area×time fixed effects. Local area refers to local authority districts, while region refers to 12 administrative regions in the UK. Borrower types are first-time borrowers, second-time borrowers and remortgagors.

	(1) I[5yr]	(2) I[5yr]	(3) I[5yr]
LTV	-0.048***	-0.046***	-0.046***
	(0.002)	(0.002)	(0.002)
I[LTV≥80%]=1 × LTV	-0.133***	-0.134***	-0.134***
	(0.003)	(0.003)	(0.003)
LTI	-0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.001)
Age	0.004	0.002	0.002
	(0.003)	(0.003)	(0.003)
Age (sq.)	-0.011***	-0.009**	-0.009**
	(0.004)	(0.004)	(0.004)
Loan Term	-0.029***	-0.028***	-0.028***
	(0.001)	(0.001)	(0.001)
Local HP Growth		-0.005*	-0.005*
		(0.003)	(0.003)
Local HP Volatility		0.001	
		(0.002)	
Local HP Beta			-0.002*
			(0.001)
Year-Month FE	✓	✓	✓
Local-Authority×Time FE	✓		
Region×Time FE		✓	✓
Lender×Time FE	✓	✓	✓
Borrower-Type FE	✓	✓	✓
Loan-Decile FE	✓	✓	✓
Sales-Channel FE	✓	✓	✓
Observations	2,865,661	2,865,661	2,865,661
R^2	0.15	0.14	0.14

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Baseline Calibration of Model Parameters

This table provides an overview of calibrated model parameters for the baseline lifecycle model. Real interest rate parameters are estimated using UK average annual rates on 5-year inflation-indexed gilts between 1987 to 2017, and 1-year real rates deflated using 1-year ahead inflation expectations. House price parameters are estimated using the UK annual house price index between 1987 to 2017. The average loan-to-income ratio is estimated based on PSD data between 2013 and 2017 of first-time buyers within the LTV band of 80-85%, and is converted to an loan-to-after-tax-income ratio using the 2017 effective UK tax rate. The long-term and short-term contract fixation lengths are based on the two most common types of products in the PSD data. The 5-year to 2-year swap rate premium is based on average UK swap rates between 2013 and 2017 using yield curve data from the Bank of England. The mortgage rate premium is computed as the difference between the 2-year 60% LTV mortgage rate and the 2-year UK swap rate over the same time period. The interest rate premia are extracted from a regression (see specification in Figure D.10a) using PSD loan-level data between 2013 and 2017. The revert rate premium is computed as the difference between the average revert rate and the 2-year 60% LTV mortgage rate.

Parameter		**Value**	**Source**
Panel A: Household preferences			
Risk aversion	γ	3	Literature
Time discount rate	δ	0.02	Literature
Panel B: Interest rates			
Mean of log real rate	μ_r	0.0164	UK (1987-2017)
Standard deviation of log real rate	σ_r	0.0193	UK (1987-2017)
Autoregression coefficient of log real rate	ρ_r	0.95	UK (1987-2017)
Panel C: House prices			
Mean of house price shock	μ_h	0.0258	UK (1987-2017)
Standard deviation of house price shock	σ_h	0.077	UK (1987-2017)
Loan-to-income ratio (85% LTV)	LTI	3.56	PSD (2013-2017)
Loan-to-after-tax-income (85% LTV)		4.82	Computed (tax rate of 35.5%)
Panel D: Income			
Standard deviation of transitory income shock	σ_ϵ	0.1	Literature
Panel E: Mortgage rates and fixation length			
Fixation length of long-term contract (years)	θ_{LT}	5	PSD
Fixation length of short-term contract (years)	θ_{ST}	2	PSD
Mortgage rate premium (bp)	ρ^m	93	Bank of England database, 2yr 60% LTV rate (2013-2017)
2yr 70-75% LTV premium (bp)	$\rho^{2,75-75}$	2	PSD (2013-2017)
2yr 75-80% LTV premium (bp)	$\rho^{2,75-80}$	15	PSD (2013-2017)
2yr 80-85% LTV premium (bp)	$\rho^{2,80-85}$	31	PSD (2013-2017)
2yr 85-90% LTV premium (bp)	$\rho^{2,85-90}$	103	PSD (2013-2017)
2yr 90-95% LTV premium (bp)	$\rho^{2,90-95}$	214	PSD (2013-2017)
5yr 70-75% LTV premium (bp)	$\rho^{5,75-75}$	21	PSD (2013-2017)
5yr 75-80% LTV premium (bp)	$\rho^{5,75-80}$	32	PSD (2013-2017)
5yr 80-85% LTV premium (bp)	$\rho^{5,80-85}$	57	PSD (2013-2017)
5yr 85-90% LTV premium (bp)	$\rho^{5,85-90}$	108	PSD (2013-2017)
5yr 90-95% LTV premium (bp)	$\rho^{5,90-95}$	217	PSD (2013-2017)
Revert rate premium	ρ^{REV}	269	Bank of England database (2013-2017)

Table 3: Long-Term Contract Shares

This table shows the simulated long-term contract shares given optimal household choice under different scenarios. The columns show results taking pricing as given for low-(70%) and high-(90%) LTV borrowers, and under expected cost pricing (imposing a collateral term premium of zero), respectively. The rows show different scenarios for house price growth and risk, and interest rate risk. The long-term contract shares are computed as the share of household-year observations that are under a long-term, compared to a short-term contract, over the first ten years since loan origination (Panel A) and over the entire maturity of the loan, 30 years (Panel B). The simulation tracks household optimal behavior given realization of shocks, based on 10,000 households for each scenario and LTV band.

	Baseline		Expected Cost Pricing	
	Low LTV	High LTV	Low LTV	High LTV
Panel A: Share on Long-Term Contract Over Initial 10 Years				
Baseline	0.95	0.35	0.96	0.93
No house price growth ($\mu_h = 0$)	0.89	0.66	0.95	0.84
No house price growth and higher risk ($\mu_h = 0$, $\sigma_h = 0.0770 * 2$)	0.87	0.80	0.86	0.81
Higher interest rate risk ($\sigma_r = 0.0193 * 2$)	0.97	0.93	0.97	0.96
No house price growth & higher interest rate risk	0.96	0.82	0.97	0.93
Panel B: Share on Long-Term Contract Over 30 Years				
Baseline	0.83	0.62	0.84	0.83
No house price growth ($\mu_h = 0$)	0.80	0.66	0.83	0.77
No house price growth and high vol ($\mu_h = 0$, $\sigma_h = 0.0770 * 2$)	0.77	0.71	0.78	0.72
Higher interest rate risk ($\sigma_r = 0.0193 * 2$)	0.91	0.89	0.89	0.89
Higher house price & interest rate risk	0.89	0.82	0.89	0.87

Table 4: Value of Long-Term Contract

This table shows the consumption-equivalent of introducing a long-term contract to an existing short-term contract under different scenarios. The columns show results taking pricing as given for low- (70%) and high-(90%) LTV borrowers, and under expected cost pricing (imposing a collateral term premium of zero), respectively. The rows show different scenarios for house price growth and risk, and interest rate risk. The consumption certainty equivalent is computed as the percentage increase in consumption across states that a household would require to reach the same life-time expected utility when a longer-term contract is available, in addition to the shorter-term contract. Life-time expected utility is simulated by tracking household optimal behavior given realization of shocks, based on 10,000 households for each scenario and LTV band.

	Baseline		Expected Cost Pricing	
	Low LTV	High LTV	Low LTV	High LTV
Panel A: Value of 5-year Contract				
Baseline	0.85	0.36	0.85	0.86
No house price growth ($\mu_h = 0$)	0.84	0.73	0.86	0.85
No house price growth and higher risk ($\mu_h = 0$, $\sigma_h = 0.0770 * 2$)	0.96	0.87	1.01	0.96
Higher interest rate risk ($\sigma_r = 0.0193 * 2$)	1.47	1.44	2.60	3.46
Higher house price & interest rate risk	2.60	3.41	2.61	3.43
Panel B: Value of 10-year Contract				
Baseline	2.03	0.74	2.03	2.04

A. Online Appendix for "The Demand for Long-Term Mortgage Contracts and the Role of Collateral"

Figure A.1: Illustration of Payment Profile for UK Mortgage Contracts with Initial Fixation Period

This figure illustrates the payment structure of a typical UK fixed-rate mortgage contract. The initial fixed-rate r^{θ} is fixed over the initial fixation length θ, throughout which prepayment penalties apply if the mortgage is prepaid. The interest rate then automatically switches to a revert rate $\tilde{r}$ until the end of the loan repayment window T, which is a floating rate that is priced over a premium over the base rate (Bank Rate). Rather than paying this rate at reset, the borrower can choose to refinance, at which point the new contract is priced.

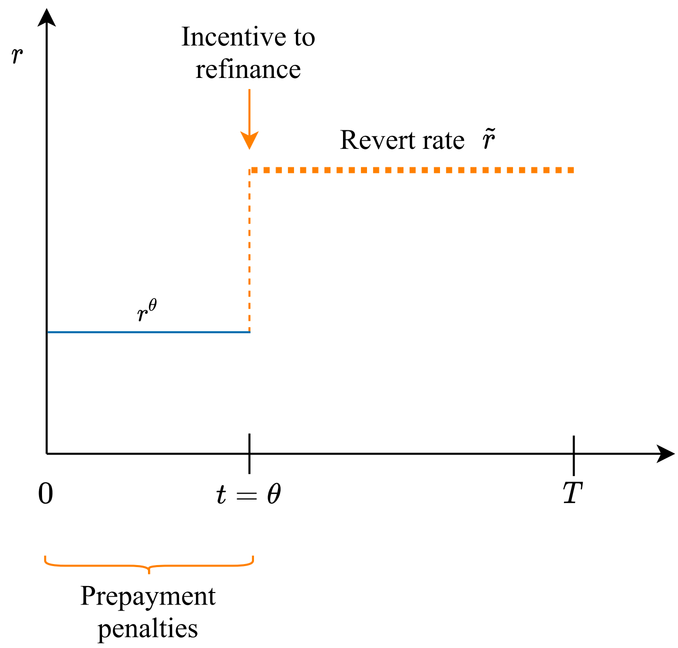


Figure A.2: Mortgage Pricing and Role of LTV

This figure shows the adjusted R^2 from a regression of observed rates on a range of fixed effects. "Base" refers to the regression including year-month, lender, buyer type (first-time buyer, second time buyer or refinance) and fixation length (less than 1, 2, 3 to 4, 5, more than 5) fixed effects, and all interaction effects. "+Income" includes income decile fixed effects and interactions with year-month to the base specification, and "+Age" and "+LTV" do this analogously for borrower age decile, and LTV band ($\leq$70%, 70-75%, 75-80%, 80-85%, 85-90%, and 90-95%) fixed effects.

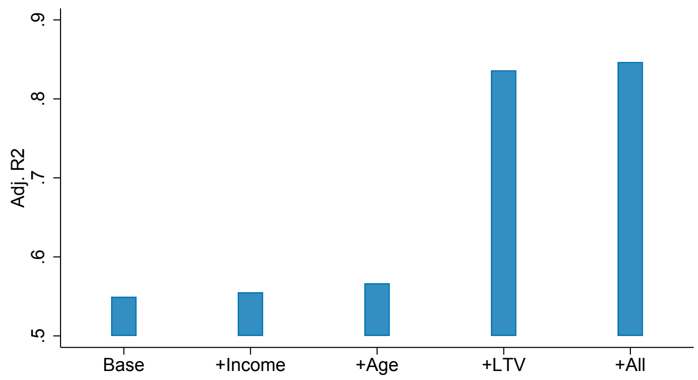


Figure A.3: Explaining Fixation Length Choice - LTV and Other Channels

This figure shows the adjusted R^2 of a regression with an indicator that takes the value 1 if the household chooses a 5-year fixed-rate contract, and 0 if the household chooses a 2-year fixed-rate contract, across a range of covariates. The first dot shows the adjusted R^2 with time (year-month), lender, location and borrower-type fixed-effects only. The following dots show the adjusted R^2 for any single variable that is added to the set of fixed effects, including the LTV band, log income, log loan size, loan-to-income (LTI) ratio, borrower age, loan term, origination fees, and local house price growth, measured as the local authority house price growth two years prior to the time of choice.

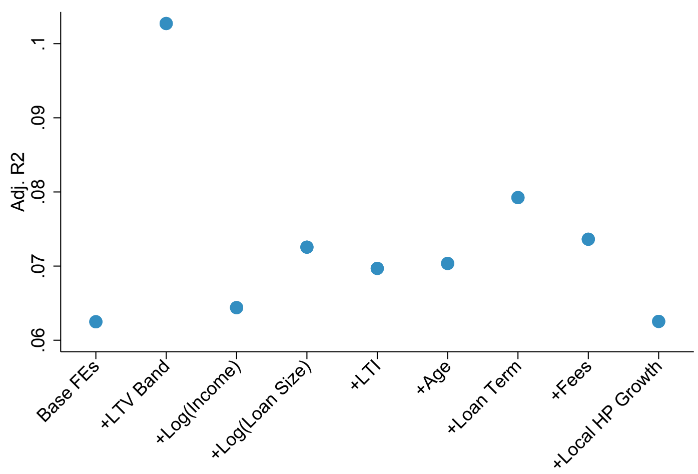


Figure A.4: Contract Choice by LTV band

This figure shows the share of newly originated fixed rate contracts by fixation length and LTV band, for loans originated between 2013 to 2017.

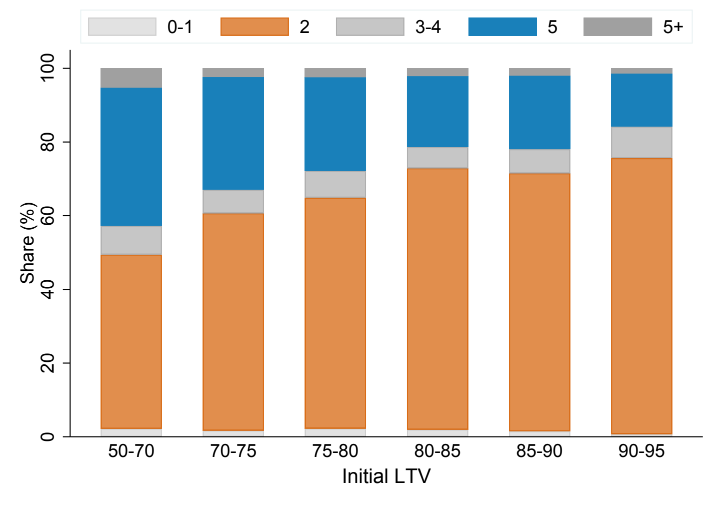


Figure A.5: Ex Post Default by Fixation Choice and LTV

These figures plot the ex post share of loans in arrears, across LTV bands and initial fixation length (2 and 5 years), for first-time borrower cohorts between 2013H2 to 2015H2. The share refers to a loan being in arrears at any point in the sample window (2013H2 to 2017H2).

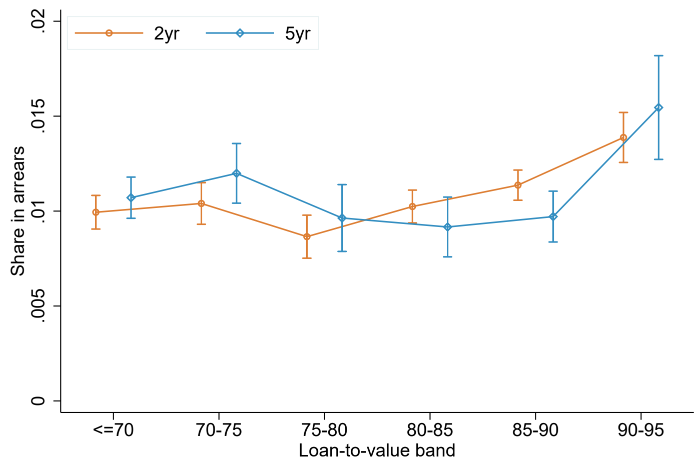


Figure A.6: Mortgage Fixation Period Across Countries

This figure shows average initial mortgage fixed-rate lengths across advanced economies, based on administrative data obtained from Badarinza et al. (2016), as at December 2013 (with the exceptions of Greece and Denmark, where data is from 2010). For Canada and Australia, this data is not available so the most frequent range is plotted, which akin to the UK, is 2 to 5 years. The household-debt-to-house-price ratio is calculated as average household debt (in USD) divided by the average house price (in USD) in 2013. Average household debt is calculated using household debt per capita (as a percentage of net household disposable income) and household disposable income from the OECD database, with the exception of Italy, where data for 2013 is not available and is replaced using total debt do household and population data from the Macrohistory Database (Jordà et al., 2017). Average house price levels are obtained from national statistics bureaus, and where price level data is not available, from other data service providers.

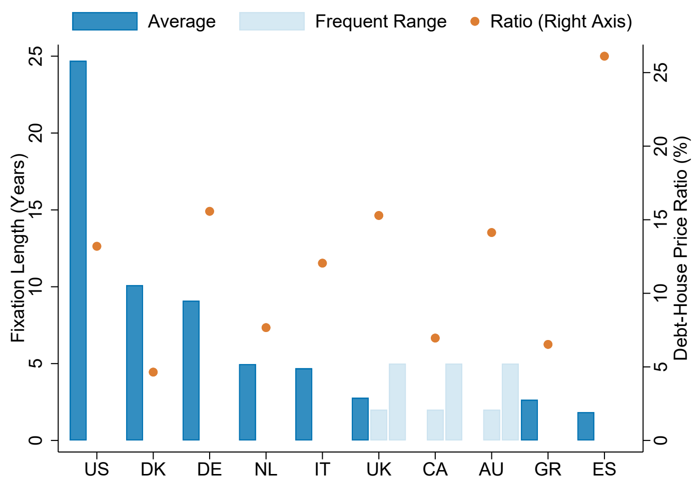


Figure A.7: Illustration of Value Function and Repricing States

This figure illustrates the time×repricing state dependencies of the value function, for $\theta^{LT} = 5$. Horizontally, each box represents a value of the value function in the time dimension. Vertically, each box represents a value of the value function in the repricing state dimension, for V_t^{LT}. Since $V_t^* = \max\{V_t^{LT}, V_t^{ST}\}$, there is only one value across all repricing states for V_t^*. V_t^{LT} tracks the value function if the household chooses a long-term contract at each point in time t, using its value across a linked chain of repricing states from $\mathcal{S} = 1$ to $\mathcal{S} = 5$.

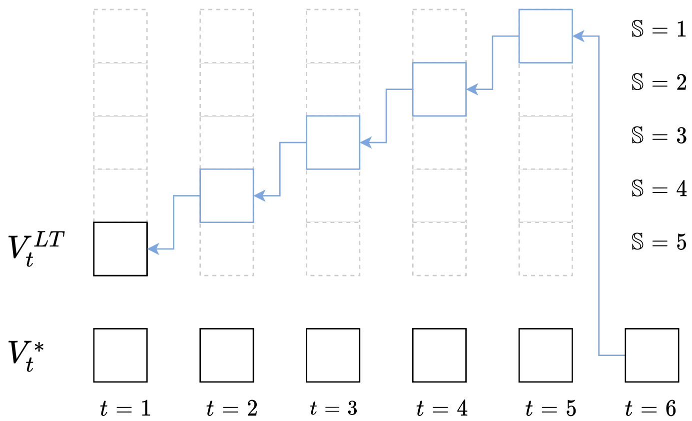


Table A.1: Summary statistics for 2-year and 5-year fixed-rate borrowers

This table compares the average and standard deviation (in parenthesis) between borrowers with a 2-year, and borrowers with a 5-year fixed-rate mortgage, across a range of observable characteristics.

	2-Year Fixed Rate	5-Year Fixed Rate
Age	36.61	38.79
	(9.03)	(9.75)
Joint Income	0.59	0.59
	(0.49)	(0.49)
Income	56,316	55,980
	(36,441)	(37,201)
Interest Rate	2.49	2.84
	(0.93)	(0.76)
Property Value	254,979	272,840
	(168,880)	(186,342)
Loan Size	172,614	157,629
	(109,938)	(106,686)
Loan Term	25.23	22.64
	(7.50)	(7.96)
LTV	71.10	61.76
	(19.95)	(21.74)
LTI	3.19	2.95
	(1.03)	(1.09)
N	1,898,660	967,001

Table A.2: 5-Year Fixation Length Contract Choice Regressions - Panel

This table shows three regressions of the probability of taking out a 5-year contract, using the borrower panel data between 2015H1 to 2017H2. The dependent variable is an indicator that takes the value 1 if the contract fixation length is 5 years, and 0 if the fixation length is 2 years. The current LTV ratio is computed as the reported current loan balance, divided by the current house price, obtained by scaling the initial house price with the local-authority-specific house price index. Column (1) estimates the regression using all observations in the panel data, column (2) imposes borrower-fixed effects and only contains pairs of observation for which a repeat choice is observed, and column (3) conditions on the subset of fixation choice pairs where the household is observed to initially originate a 2-year fixed-rate contract.

	(1) I[5yr]	(2) I[5yr]	(3) I[5yr]
I[LTV≥80%]=0 × LTV	-0.024***	-0.014	-0.017
	(0.006)	(0.010)	(0.009)
I[LTV≥80%]=1 × LTV	-0.092***	-0.028***	-0.021**
	(0.015)	(0.007)	(0.008)
Time FE	✓	✓	✓
Local-Authority FE	✓	✓	✓
Loan-Decile FE	✓	✓	✓
Lender FE	✓	✓	✓
Borrower FE		✓	✓
Observations	727,094	360,496	298,504
R^2	0.07	0.65	0.55

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Long-Term Contract Shares (Robustness)

This table shows the simulated long-term contract shares given optimal household choice under different scenarios. The columns show results taking pricing as given for low-(70%) and high-(90%) LTV borrowers, and under expected cost pricing (imposing a collateral term premium of zero), respectively. The rows show additional scenarios. The long-term contract shares are computed as the share of household-year observations that are under a long-term, compared to a short-term contract, over the first ten years since loan origination (Panel A) and over the entire maturity of the loan, 30 years (Panel B). The simulation tracks household optimal behavior given realization of shocks, based on 10,000 households for each scenario and LTV band.

	Baseline		Expected Cost Pricing	
	Low LTV	High LTV	Low LTV	High LTV
Panel A: Share on Long-Term Contract Over Initial 10 Years				
Higher risk aversion ($\gamma = 10$)	0.95	0.35	0.96	0.94
Higher time discount rate ($\beta = 0.9$)	0.95	0.35	0.96	0.93
Higher revert rate ($\rho^{REV} = 538bp$)	0.95	0.40	0.96	0.94
Panel B: Share on Long-Term Contract Over 30 Years				
Higher risk aversion ($\gamma = 10$)	0.84	0.63	0.84	0.83
Higher time discount rate ($\beta = 0.9$)	0.83	0.62	0.84	0.83
Higher revert rate ($\rho^{REV} = 538bp$)	0.83	0.63	0.84	0.83

Table A.4: Value of Long-Term Contract (Robustness)

This table shows the consumption-equivalent of introducing a long-term contract to an existing short-term contract under different scenarios. The columns show results taking pricing as given for low- (70%) and high-(90%) LTV borrowers, and under expected cost pricing (imposing a collateral term premium of zero), respectively. The rows show additional scenarios. The consumption certainty equivalent is computed as the percentage increase in consumption across states that a household would require to reach the same life-time expected utility when a longer-term contract is available, in addition to the shorter-term contract. Life-time expected utility is simulated by tracking household optimal behavior given realization of shocks, based on 10,000 households for each scenario and LTV band.

	Baseline		Expected Cost Pricing	
	Low LTV	High LTV	Low LTV	High LTV
Panel A: Value of 5-year Contract				
Higher risk aversion ($\gamma = 10$)	1.08	0.31	1.08	0.88
Higher time discount rate ($\beta = 0.9$)	0.91	0.22	0.91	1.04
Higher revert rate ($\rho^{REV} = 538bp$)	0.72	0.21	0.72	0.75

B. Dataset Construction

B.1. Stock-Flow Merge (PSD007 and PSD001) for Borrower Panel

To analyze borrower refinancing behavior and repricing of rates at the point of refinance, I merge two administrative datasets on the universe of UK mortgage borrowers. First, I observe new mortgage originations in the Product Sales Data (PSD) that is accessed through the Bank of England via a data sharing agreement with the Financial Conduct Authority. The dataset collects detailed borrower characteristics such as income, age, address, loan amount, property value, and detailed loan characteristics such as the loan maturity, interest rate, fixation length, and which lender originated the mortgage. This allows me to identify first-time buyer cohorts who newly originate their mortgage between 2013H2 to 2015H1. The origination data is available from 2005Q2 and updated at quarterly frequency up to today.

I then use a more recent additional dataset that is part of the PSD which tracks the entire stock of UK mortgages outstanding, available from 2015H1 and updated at half-yearly frequency up to today. The stock data contains information on the current interest rate type, current interest rate paid, current loan amount, current lender, and whether the loan is in arrears. I merge the stock data with the origination data to track refinancing behavior and outcomes (e.g. interest rate paid and an indicator whether the borrower is in arrears) between 2015H1 and 2017H2 for the first-time borrower cohorts identified in the origination data.

The final data has a panel format which comprises detailed borrower and loan characteristics at origination, and half-yearly updates on outcomes such as interest rates, loan amount remaining and default status. In addition to the characteristics at origination, each refinance that reflects a switch to a different lender is recorded as a new origination, so I observe updated information on income and other borrower characteristics if the borrower does a so-called "external" refinance. This is in contrast to an "internal" refinance where the lender refinances into a different contract and interest rate, but stays with the current lender. I identify internal and external refinancers as follows: the data records if the borrower is on the revert rate, so a refinance requires the borrower to either move from a revert rate to a fixed-rate contract, or move from an existing fixed-rate contract into a new fixed-rate contract. External refinances are recorded in the origination data, so if a borrower is recorded as a refinancer in the origination data, the lender changes, and the interest rate changes in that period, I classify the borrower as an external refinancer. If only the interest rate changes but there is no entry in the orgination data and the lender remains the same, I classify this as an internal refinance.[43]

[43] Reassuringly, the resulting numbers are very similar to those provided by Belgibayeva et al. (2020) who obtain explicit data on internal refinancing through a survey of the 20 largest UK lenders for 2-year fixed rate borrowers in 2013.

For the 2013H2 first-time borrowers who took out a 2-year fixed rate contract, about 55% refinance internally, and around 30% refinance externally by 2016H1, i.e. within six months of the end of the fixed rate period in 2015H2. Each half-year origination cohort comprises around 150,000 first-time borrowers, leaving me with 721,060 unique borrowers, and around 5.5 million borrower-half-year observations between 2015H1 to 2017H2.

The two datasets do not have unique borrower identifiers, but a borrower can be identified up to an (anonymized) date of birth and six-digit postcode which is approximately the building block in which a UK household resides. Table B.5 illustrates the quality of the merge. The mortgage stock data starts in 2015H1 but in order to observe a longer time-series of outcomes, I start with a borrower cohort in 2013H2. That means that borrowers are not matched in 2015H1 if there is a pure merging error (e.g. because the borrower identification is not unique), or if borrowers prepay or default and leave the sample prior to 2015H1. In addition, the data is less complete in 2015H1 compared to 2015H2 onwards. I hence compare the observations that are not matched to the 2015H2 stock data across first-time borrower cohorts in Table B.5. From the share of "not matched" observations, it can be seen that 1.8% of first-time borrowers in 2015H2 cannot be matched to the stock data in 2015H2, which provides an estimate of unmatched observations driven by pure merging error.

Going from the origination cohort in 2015H1 back to 2013H2, around 1-2% more observations are unmatched from half-year to half-year, providing an estimate of the share of borrowers that leaves the stock data due to prepayment or porting the mortgage (for instance if the borrower moves to another house) or default, at half-yearly frequency. Note that because mortgages are portable in the UK, mortgages could show up in the data with the same borrower but a new house address, which I cannot track due to the borrower identification procedure described above. Table B.6 compares the average characteristics (with standard deviations) of borrowers and loans for matched and unmatched observations. Unmatched borrowers are slightly older, have larger incomes, loan sizes and property values, and lower loan-to-income and loan-to-value ratios, tentatively suggesting that the unmatched borrowers seem to reflect movers rather than more risky borrowers who have defaulted.

Lastly, the origination data prior to 2015H1 does not require to report the fixation length, so I do not observe the fixed-rate period for about 40% of first-time borrowers. The sample for which fixation lengths are observed appears to be a highly balanced sample compared to where it is not observed, as noted by Best et al. (2020) and demonstrated in Table B.7. I hence proceed with the remaining sample of 414,643 first-time borrowers for which this key variable is observed, resulting in a panel of around 2.8 million borrower-half-year observations.

Table B.5: Matching to 2015H2 mortgage stock

This table shows the share of borrowers in each first-time borrower cohort between 2013H2 and 2015H2 in the origination data that can be matched to the stock of all mortgages outstanding in 2015H2.

	2015H2 data					
FTB cohort	Not matched		Matched		Total	
	No.	%	No.	%	No.	%
2013H2	8,641	6.0%	135,156	94.0%	143,797	100.0%
2014H1	5,761	4.1%	134,714	95.9%	140,475	100.0%
2014H2	4,832	3.2%	147,732	96.8%	152,564	100.0%
2015H1	4,208	3.3%	121,642	96.7%	125,850	100.0%
2015H2	2,841	1.8%	155,533	98.2%	158,374	100.0%
Total	26,283	3.6%	694,777	96.4%	721,060	100.0%

Table B.6: Balance of matched observations

This table compares the average and standard deviation (in parenthesis) between the matched and unmatched sample shown in Table B.5 across a range of observable characteristics.

	Not matched	Matched
Age	32.43	31.10
	(8.15)	(7.04)
Joint Income	0.62	0.52
	(0.49)	(0.50)
Income	55,941	44,731
	(37,997)	(26,664)
Interest Rate	3.44	3.39
	(0.92)	(0.98)
Property Value	231,813	196,274
	(169,121)	(128,351)
Loan Size	163,467	146,385
	(104,402)	(87,692)
Loan Term	26.71	28.10
	(6.67)	(6.14)
LTV	74.10	77.11
	(17.90)	(16.67)
LTI	3.14	3.38
	(1.10)	(0.94)
Origination Year	2014	2014
	(0.77)	(0.74)
N	26,283	694,777

Table B.7: Sample selection balance (fixation length observed)

This table compares the average and standard deviation (in parenthesis) between the subset of observations for which the fixation length is observed and that for which it is not, in the matched sample across a range of observable characteristics.

	Observed	Not observed
Age	31.17	31.12
	(7.08)	(7.10)
Joint Income	0.53	0.52
	(0.50)	(0.50)
Income	45,520	44,563
	(27,052)	(27,402)
Interest Rate	3.35	3.50
	(1.00)	(0.93)
Property Value	202,989	190,188
	(133,626)	(125,063)
Loan Size	149,795	143,213
	(91,227)	(84,286)
Loan Term	28.08	28.01
	(6.09)	(6.26)
LTV	76.60	77.54
	(17.52)	(15.56)
LTI	3.38	3.36
	(0.95)	(0.94)
Origination Year	2015	2014
	(0.65)	(0.50)
N	414,643	306,417

C. Household Refinancing Behavior with Prepayment Penalties

I use the borrower panel to study refinancing behavior over time. Figure C.8 plots the cumulative share of borrowers who have refinanced at least once over time, by contract fixation period.[44] For borrowers with an initial 5-year contract, the share is very low throughout the sample window between 2013H2 and 2017H2, with only around 5% of borrowers refinancing out of their initial contract by the end of 2017, i.e. after four years since origination. For borrowers with an initial 2-year contract, there is a slight increase in refinancers in 2015H1, and a large jump in refinancers in 2015H2 as expected, as the initial fixation period ends and borrowers are moved onto the revert rate unless they refinance at this point.[45] At 2015H2, in the half-year reporting window that tracks outcomes two years after the initial contract origination, the share of refinancers jumps to around 75%. If one takes a 6-month window around the scheduled refinance date, i.e. including 2016H1, that share rises to around 85%. The share rises further to around 90 to 95% when looking at the full four-year reporting window.[46] In sum, almost all first-time borrowers remain in the contract until the end of the initial fixation window, and only around 5% of borrowers exit the contract early and pay a prepayment penalty.[47]

I can further illustrate the binding nature of prepayment penalties during a period of strong house price growth. Figure C.9 shows ex post interest rate realizations for the cohort of 2013H2 first-time borrowers, split by initial fixation window. Consistent with contract features, average rates remain stable over the sample window from 2013H2 to 2017H2 for borrowers with a 5-year contract who lock in the initial rate at 2013H2. For borrowers with a 2-year fixation window, the interdecile range widens visibly in 2015H2. Panel B shows that for borrowers with a high initial LTV (85-90% LTV band), borrowers with a 2-year fixed rate window experience a sharp decrease in average rates paid in 2015H2, while borrowers with a 5-year contract continue to pay the fixed rate, despite the incentive to switch into a lower 2-year fixed rate, absent prepayment penalties.

[44] I focus on the first-time borrower cohort of 2013H2 in order to maximize the sample window over which outcomes can be observed (four years until 2017H2), and confirm that the results are robust when using other cohorts or when pooling all cohorts.

[45] The slight increase in 2015H1 is partly driven by some 2-year windows ending in that half-yearly reporting period, but that were originated in 2013H2, so comprises many "on schedule" refinances.

[46] This gradual increase over time comprises both refinancers who exhibit inertia, i.e. refinance late but could have refinanced and potentially saved cost relative to the revert rate, and borrowers who were not able to refinance at that time, for instance if their LTV exceeded 100%, but were able to do so at a later point (Keys et al., 2016; Andersen et al., 2020; Fisher et al., 2021).

[47] Inspecting this subset of borrowers further, these households have larger incomes and smaller loan balances, which could also be consistent with prepayment in order to move. Mortgages are portable in the UK and so some of the households that exit early could be porting their mortgage to another property without paying a prepayment penalty. I cannot verify the share of porters as these transactions would show up as a new loan in the data with a different location, and the data does not allow to track households across locations.

Figure C.8: Refinancing behavior

This figure shows the cumulative share of borrowers who refinance (either with their existing lender or with a different lender), for borrowers who chose a contract with an initial 2-year, or 5-year fixation length, respectively, based on the 2013H2 cohort of first-time borrowers.

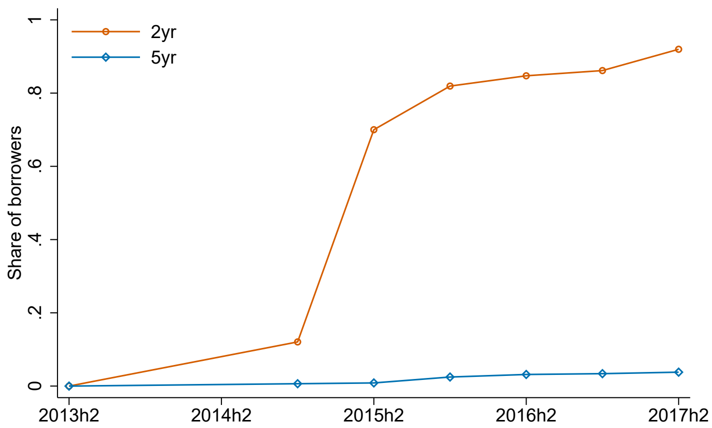
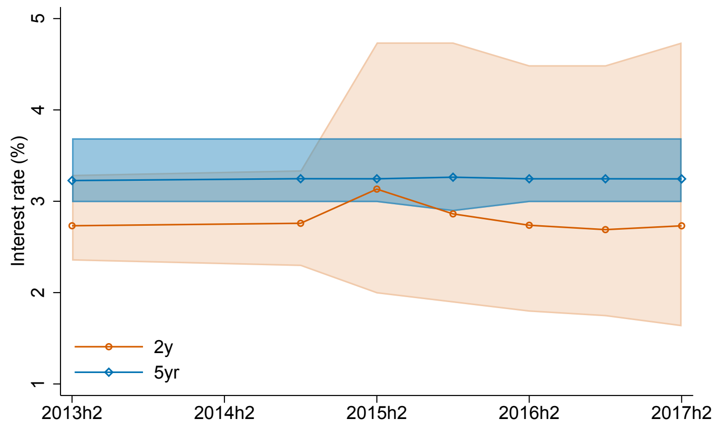


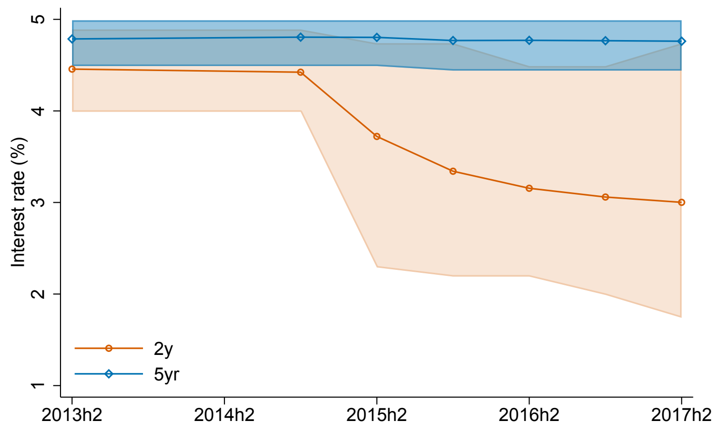
Figure C.9: Ex Post Repricing

This figure tracks the 2013H2 cohort of first-time borrowers and the distribution of mortgage rates paid based on the interdecile range (shaded area), and average rate (connected dots), over time, for 2- and 5-year fixed-rate borrowers who stay with their initial lender, respectively. Panel A shows rates paid for borrowers with an initial LTV between 70-75%, and Panel B shows the equivalent for borrowers with an initial LTV between 85-90%.

(a) Low LTV



(b) High LTV



D. Relative Cost of Longer-Term Mortgages Decomposition

Denote the per-period mortgage rate $r_t^{m,\theta}$ where superscript m refers to the mortgage rate, and $\theta \in \{\theta^{ST}, \theta^{LT}\}$ is the length (in years) over which the rate stays fixed. Further denote the expected difference between the longer-term θ^{LT}-period mortgage rate, and the average rate when rolling over a sequence of shorter-term θ^{ST}-period contracts given an initial LTV as $\Delta^{\theta^{LT},\theta^{ST}}(LTV_t)$:[48]

$$\Delta^{\theta^{LT},\theta^{ST}}(LTV_t) \equiv E_t\left[r_t^{m,\theta^{LT}}(r_t, LTV_t) - \frac{1}{n}\sum_{i=0}^{n-1} r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i}, LTV_{t+\theta^{ST}\times i})\right], \quad n = \theta^{LT}/\theta^{ST}. \tag{10}$$

For notational simplicity, let $\theta^{LT} = n \cdot \theta^{ST}$ where n is an integer. Both the longer-term mortgage rate $r_t^{m,\theta^{LT}}$ and the shorter-term rates $r_t^{m,\theta^{ST}}$ depend on the base (i.e. aggregate) interest rate r_τ, and LTV_τ at the time of pricing τ. For the longer-term mortgage rate, the mortgage is priced in the initial period t. For the shorter-term rate sequence, the rate gets repriced with each new contract, i.e. every θ^{ST} years. By adding and subtracting the average of the sequence of shorter-term rates at current LTV levels, the expression can be rewritten as:

$$\begin{aligned}\Delta^{\theta^{LT},\theta^{ST}}(LTV_t) = {} & E_t\left[r_t^{m,\theta^{LT}}(r_t, LTV_t) - \frac{1}{n}\sum_{i=0}^{n-1} r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i}, LTV_t)\right] \\ & + E_t\left[\frac{1}{n}\sum_{i=0}^{n-1}\left(r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i}, LTV_t) - r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i}, LTV_{t+\theta^{ST}\times i})\right)\right]\end{aligned} \tag{11}$$

The first term in equation 11 can further be split into an LTV-insensitive part of the mortgage rate, where $LTV \leq \underline{x}$, with the LTV pricing threshold $\underline{x}$ typically being 60 to 70%, and the remaining LTV-sensitive part for which $LTV > \underline{x}$. Define $r_t^{m,\theta}(r_t) \equiv r_t^{m,\theta}(r_t, LTV_t \mid LTV_t \leq \underline{x})$, i.e. assuming that mortgage rates in the lowest LTV band are essentially collateral risk-free, LTV can be omitted in the notation for mortgage rates with an LTV below $\underline{x}$. And denote $\rho_t^{\theta,LTV}$ the credit spread, i.e. the rate difference between a mortgage with fixation length θ with some LTV, and the LTV-insensitive mortgage rate with an LTV below $\underline{x}$:

$$\rho_t^{\theta,LTV} = r_t^{m,\theta}(r_t, LTV_t) - r_t^{m,\theta}(r_t). \tag{12}$$

Combining equations 11 and 12, we obtain

[48] This builds on the framework by Campbell and Shiller (1991) for risk-free bonds.

$$\Delta^{\theta^{LT},\theta^{ST}}(LTV_t) = \underbrace{E_t\left[r_t^{m,\theta^{LT}}(r_t) - \frac{1}{n}\sum_{i=0}^{n-1} r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i})\right]}_{\text{(I) Bond Term Premium } \kappa^{\theta^{LT},\theta^{ST}}}$$

$$+ \underbrace{E_t\left[\rho_t^{\theta^{LT},LTV_t} - \frac{1}{n}\sum_{i=0}^{n-1} \rho_{t+\theta^{ST}\times i}^{\theta^{ST},LTV_t}\right]}_{\text{(II) LTV Pricing Differential } \Delta\rho^{\theta^{LT},\theta^{ST}}(LTV_t)}$$

$$+ \underbrace{E_t\left[\frac{1}{n}\sum_{i=0}^{n-1}\left(r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i}, LTV_t) - r_{t+\theta^{ST}\times i}^{m,\theta^{ST}}(r_{t+\theta^{ST}\times i}, LTV_{t+\theta^{ST}\times i})\right)\right]}_{\text{(III) Credit Repricing Benefit } \Delta r^{m,\theta^{ST}}(LTV_t)}. \quad \text{(13a)}$$

Combining the last two terms (II and III) as the collateral term premium

$$\phi^{\theta^{LT},\theta^{ST}}(LTV_t) \equiv \Delta\rho^{\theta^{LT},\theta^{ST}}(LTV_t) + \Delta r^{m,\theta^{ST}}(LTV_t) \quad \text{(13b)}$$

we can write

$$\Delta^{\theta^{LT},\theta^{ST}}(LTV_t) = \underbrace{\kappa^{\theta^{LT},\theta^{ST}}}_{\text{(I) Bond Term Premium}} + \underbrace{\phi^{\theta^{LT},\theta^{ST}}(LTV_t)}_{\text{(II) + III = Collateral Term Premium}}. \quad \text{(13c)}$$

Equation 13 decomposes the expected yield difference between the longer-term mortgage contract and sequence of shorter-term contracts into two parts: the first is a familiar-looking expression based on the expectations theory of the term structure of interest rates (Campbell and Shiller, 1991), i.e. a bond term premium κ that is independent of the level of LTV. I later show that this bond term premium in mortgage rates of differing fixation lengths maps to the funding cost differential between interest rate swap rates of differing maturities. The second term is a collateral term premium ϕ, i.e. a term premium over and above the lowest LTV band, which depends on the level of collateral, captured by LTV. It has two components: first, the expected credit pricing differential in interest rate premia for a given current LTV (i.e. initial LTV at origination time t) between the longer-term and shorter term contracts ($\Delta\rho^{\theta^{LT},\theta^{ST}}(LTV_t)$). And second, the yield difference between the shorter-term mortgage sequence with and without LTV repricing ($\Delta r^{m,\theta^{ST}}(LTV_t)$). This component reflects the short-term rate path differential due to changes in credit risk over the long-term contracting horizon, the credit repricing benefit of the shorter-term contract sequence. In the data, I show that the collateral term premium is positive and increasing in LTV, due to a small positive LTV pricing differential at low levels of LTV, and a large credit repricing benefit at high levels of LTV given a declining LTV path over time, with positive expected house price growth and loan repayment. In contrast, for the collateral term premium to be zero, the pricing differential between long-and short-term mortgages would have to be negative, in order to offset the expected declining rate path of the shorter-term contract sequence.

D.1. Mapping Pricing Decomposition to the Data

This subsection maps the components of the mortgage term premium to the data, and summarizes the results in Table D.8.

To provide a concrete example of equation 13 and to map it to the data on 2 and 5-year fixed-rate mortgages, let $\theta^{LT} = 5$ and $\theta^{LT} = 2$. For t=0 and an initial LTV (LTV_t) of 90% we get:[49]

$$
\begin{aligned}
(14)\quad \Delta^{5,2} &= \underbrace{E_0\left[r_0^{m,5}(r_0) - \frac{1}{2.5}\left(r_0^{m,2}(r_0) + r_2^{m,2}(r_2) + \frac{1}{2}r_4^{m,2}(r_4)\right)\right]}_{\text{(I) Bond Term Premium } \kappa^{5,2}} \\
&+ \underbrace{E_0\left[\rho_0^{5,90} - \frac{1}{2.5}\left(\rho_0^{2,90} + \rho_2^{2,90} + \frac{1}{2}\rho_4^{2,90}\right)\right]}_{\text{(II) LTV Pricing Differential } \Delta\rho^{5,2}(90)} \\
&+ \underbrace{E_0\left[\frac{1}{2.5}\left(r_0^{m,2}(r_0,90) + r_2^{m,2}(r_2,90) + \frac{1}{2}r_4^{m,2}(r_4,90) - \left(r_0^{m,2}(r_0,90) + r_2^{m,2}(r_2,LTV_2) + \frac{1}{2}r_4^{m,2}(r_4,LTV_4)\right)\right)\right]}_{\text{(III) Rate Path Differential with LTV Repricing } \Delta r^{m,\theta^{ST}}(LTV_t)}
\end{aligned}
$$

The following discusses the empirical equivalents of equation 14 for different levels of initial LTV.

(I) Bond Term Premium and Funding Cost Spread (κ). I find that variation in the bond term premium over time is captured well by variation in duration-matched swap rates and hence maps to lenders' relative funding cost. Lenders typically enter a swap contract which matches the initial fixation period of the mortgage contract to hedge interest rate exposure, by paying a floating rate plus premium and receiving a fixed rate for funding. The 5-year mortgage contract requires a 5-year swap rate, while the 2-year contract requires a 2-year swap rate. Using monthly average data from 2013 to 2017, I find that the 5-year rate lies above the 2-year rate throughout, consistent with a positive bond term premium included in the 5-year mortgage rate relative to the 2-year rate. I further find that the difference between the 5-year and 2-year mortgage rate at 70% LTV, i.e. the term premium κ as defined above, as well as the funding cost spread between 5-year and 2-year interest swap rates appear strongly correlated. The bond term premium is around 50 basis points over this period.

(II) Credit Spread for a Given LTV and LTV Pricing Differential ($\Delta\rho$). Column 1 in Table D.8 compares pricing across 5-year and 2-year contracts by computing the credit pricing differential $\Delta\rho$ across the LTV distribution. This differential is positive at an LTV up to 85%, and around

[49] Note that because in this case θ^{LT}/θ^{ST} is not an integer, the last 2-year contract is divided by two to reflect the same contract horizon as $\theta^{LT} = 5$.

zero and similar to 2-year contracts, for high LTV levels greater than 85%. A pure pricing differential could be consistent with some degree of selection into 5-year fixed-rate contracts at low levels of LTV. In order to arrive at this result, I first compute $\rho_t^{\theta,LTV}$ by extracting the credit spread paid across LTV bands for 2 and 5-year contracts relative to the lowest LTV band ($\leq$ 70%) from the data. I follow the typical pricing schedule which varies across LTV bands in steps of five percentage points, starting from the LTV pricing threshold $\underline{x}$ = 70%. Figure D.10a plots the credit spread paid across LTV bands, [0-70]%, (70-75]%, (75-80]%, (80-85]%, (85-90]%, and (90-95]%), extracted from a pooled regression of interest rates on LTV bands and fixation period length (two or five years), controlling for year-month, lender, buyer-type and year-month×lender fixed effects, using data from 2013 to 2017.[50] The interest rate premia are estimated jointly for 2-year and 5-year fixed rate contracts in the same regression, with 2-year fixed rate contracts as the base category, and 5-year fixed rate contracts with an additional interaction term.[51]

(III) Credit Repricing Benefit ($\Delta r(LTV)$). Column 2 in Table D.8 shows the expected rate path differential $\Delta r^{m,\theta^{ST}}(LTV_t)$ by computing the difference between the short-term rate given the initial LTV, and the average short-term rate path with repricing of LTV over time. This rate path differential is close to zero for an LTV below 85%, and rises to 69 basis points for an LTV of 95%. In order to compute the expected rate path with LTV repricing, I calibrate the house price process using UK data from 1987 to 2017. Real house prices are assumed to follow a lognormal distribution and are calibrated to have mean μ_h = 0.0258 and standard deviation σ_h = 0.0770. Nominal house prices are deflated using RPI. The simulation is done for a fully-amortizing loan, repaid over 30 years.

Collateral Term Premia. Column 3 in Table D.8 computes the collateral term premium as the sum of the LTV Pricing Differential (in column 1) and Rate Path Differential (in column 2), and is plotted in Figure D.10. The collateral term premium rises from 18 basis points at 75% LTV, to 72 basis points at 95% LTV. The overall mortgage term premium is hence increasing in LTV, implying that the cost of insurance via longer-term contracts is increasing in borrower riskiness. Two alternative ways of framing the magnitude of the collateral term premium are outlined in the following.

[50] As a robustness check, the magnitudes remain very similar when estimating the regression on the full origination data between 2005Q2 and 2017Q4, and including more loan-specific fixed effects and household controls.

[51] In addition, the term premium κ can also be directly extracted from this regression, as the average difference between 2 and 5-year fixed rate contracts for the $\leq$70% LTV band, yielding 53 basis points, which is very similar to aggregate data of 52 basis points using the Bank of England Database.

Expected Cost Pricing (Collateral Term Premium of Zero). An alternative way to interpret Column 2 in Table D.8 is to think of the rate path differential as the magnitude by which the 5-year contract should be cheaper than the 2-year contract - i.e. for the collateral term premium to be zero, 5-year contracts would have to price in the declining expected rate path of the 2-year contract sequence, and the 5-year LTV pricing curve would be weakly lower than the 2-year curve at each LTV band. This effect would be even more pronounced when comparing the short-term rate path with LTV repricing over a 10-year fixation window. This counterfactual pricing scheme is shown for 5- and 10-year contracts in Figure D.10a.

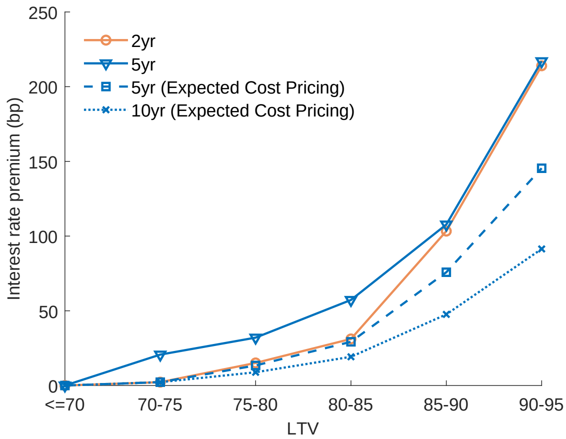
Collateral Term Premia Expressed as Percentage of Mortgage Cost. Column 4 in Table D.8 expresses the collateral term premium as a percentage of mortgage cost for a representative household, as an alternative measure for the magnitude of the premium. Column 5 in Table D.8 provides an all-in cost measure of the total term premium, by including a fixed cost of refinancing k whenever a new contract is originated, and the bond term premium κ. The expected cost comparison is based on the expected mortgage payments over a window of 5 years.[52] With bond term premia and refinancing cost included, households with an LTV below 70% pay 4.1% more in mortgage payments over the initial 5 years, while households with an LTV of 95% pay 12.8% more for the 5-year contract compared to rolling over a 2-year contract sequence.

[52] Results are similar when comparing a 10-year window with two 5-year contracts, and five 2-year contracts.

Figure D.10: Collateral Term Premium

[p] Panel A of this figure plots the credit spread paid across loan-to-value (LTV) bands (≤70%, (70-75]%, (75-80]%, (80-85]%, (85-90]%, and (90-95]%), by extracting LTV-band fixed effects from a regression of interest rates on LTV bands and fixation period length (2 or 5 years), controlling for year-month, lender, buyer-type, year-month×lender fixed effects, using data from 2013 to 2017. The credit spreads are estimated in the same regression for 2-year and 5-year fixed rate contracts, with 2-year fixed rate contracts as the base category, and 5-year fixed rate contracts with an additional interaction term. Panel A further shows counterfactual interest rate premia for 5-year and 10-year fixed-rate contracts that would equalize the expected average cost of rolling over a matching sequence of 2-year fixed rate contracts given 2-year fixed rate LTV premia over five and ten years ("expected cost pricing", i.e. imposing a collateral term premium of zero), respectively. Panel B shows the decomposition of the collateral term premium into the interest rate differential due to LTV repricing (as illustrated in Panel A) and the interest rate pricing differential across 2-year and 5-year contracts (the difference between the 5-year and 2-year fixed-rate pricing curve in Panel B), across LTV bands.

(A) LTV Pricing (ρ^2 and ρ^5)



(B) Collateral Term Premium ($\phi^{5,2}$)

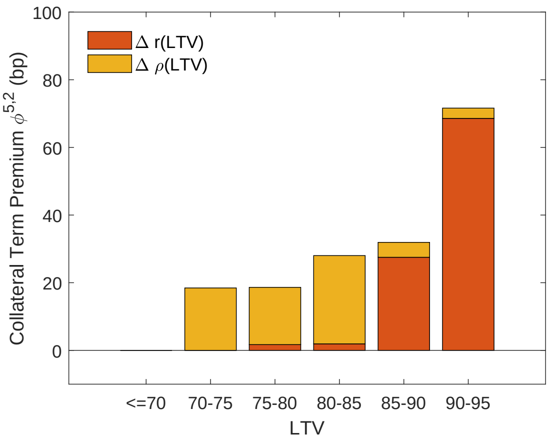


Table D.8: Collateral Term Premium and Total Cost

This table shows the components of the collateral term premium, the pricing differential across 5- and 2-year fixed rate contracts ($\Delta\rho$), the interest path differential of the shorter-term rate (Δr), and the collateral term premium expressed in basis points (column 3) and as a percentage of mortgage cost (column 4) over the first five years of the loan, across LTV bands, under the baseline calibration. Column 5 shows a total cost measure over the first five years of the loan, taking into account mortgage cost, the fixed cost of refinancing at each new loan origination, and the bond term premium κ.

			Collateral Term Premium		Total Cost
LTV band	$\Delta\rho$	Δr	ϕ (bp)	% (Cost)	%
[0-70]	0	0	0	0.0	4.1
(70-75]	18	0	18	2.4	6.5
(75-80]	17	2	19	2.5	6.7
(80-85]	26	2	28	3.7	7.9
(85-90]	4	28	32	4.0	8.1
(90-95]	3	69	72	8.7	12.8

E. Model Appendix

E.1. Numerical solution

Discretization. The six state variables are discretized as follows. Net financial wealth (X) is normalized by permanent income at age 35. Grid points are equally spaced on a grid between 0 to 22.5 in steps of 0.025, yielding 901 grid points. Time is measured in years between 30 to 80 (working age from 30 to 60, and retirement from 60 to 80), yielding 51 grid points. The LTV grid takes values between 30 to 150, in steps of 1 percentage points, yielding 121 grid points. The interest rate process is discretized using five states using the method by Rouwenhorst (1995), which has been shown by Kopecky and Suen (2010) to yield better results when approximating very persistent AR(1) processes compared to Tauchen (1986); Tauchen and Hussey (1991). The repricing state variables $\mathcal{S}^{\theta^{LT}}$ and $\mathcal{S}^{\theta^{ST}}$ take 5 (or 10) and 2 states, respectively. Transitory income shocks and house price shocks are discretized on an equal-spaced grid between -4 and 4 standard deviations.[53] Consumption is placed on the same grid as net financial wealth, while mortgage contract choice is discrete with two outcomes (short- or longer-term contract).

Model solution. Optimal consumption and mortgage fixation choice policy functions are found as the maximum for each combination of discretized states in the state space, i.e. $901 \times 51 \times 121 \times 5 \times (5+2)$ (for the 5-year contract) or $901 \times 51 \times 121 \times 5 \times (10+2)$ (for the 10-year contract), yielding around 195 to 334 million combinations. The model is solved separately under different specifications, and under observed vs. expected cost pricing, which is computationally intensive and parallelized on the Imperial HPC cluster.

Simulation. I use the optimal policy functions for consumption and mortgage fixation choice to simulate the model. Households are initialized at $t = 1$ with zero net financial wealth and a random distribution of transitory income shocks, and no house price or interest rate shocks, in order to allow households to start at the same initial LTV band and interest rate. The initial base interest rate places households in the second lowest out of five states, in order to reflect the current environment with greater emphasis on the risk of rising rates. The simulation is done separately for households starting at different LTV levels, but uses the same shocks. Each simulation is done for 10,000 households.

[53] Tail probabilities exceeding the LTV grid are added to the lowest and highest grid point, respectively.