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Abstract

We quantify the housing-consumption channel in mortgage demand according to which households borrow more following house-price increases since housing and non-housing consumption are imperfect substitutes. To identify this channel, we take a structural approach to mortgage demand and supply, exploiting exogenous variation in house-price growth and a unique data set with matched transaction-price and mortgage information. We estimate an elasticity of mortgage borrowing to house-prices of 0.82. Counterfactual analysis of the general-equilibrium of housing and mortgage markets shows that, sans housing-consumption channel, mortgage and house-price growth in the UK would have been 50% and 31% lower, respectively, since the 1990s.

Key words: House prices, mortgage demand, housing consumption, consumption channel, property taxes.

JEL classification: G11, G21, R21.

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1 Introduction

Excessive household debt is one of the most important threats to economic and financial stability. It tends to amplify the effects of economic crises since it can increase mortgage default rates, reduce labour supply, collapse consumer spending and lower output.[1] In most countries, mortgages account for the majority of household debt. For instance, 91% of all household debt is associated with a mortgage on a property (ONS, 2019) in the UK. Against the background of high household debt (and leverage), high interest rates and historically high house prices in cities around the world, our understanding of the role of house prices in driving mortgage demand is still quite incomplete.

Existing literature has demonstrated a positive relationship between aggregate mortgage lending and house prices, and proposed different mechanisms for the co-movement. First, if house prices increase, owners *want* to borrow more to convert the increase in wealth into an increase in consumption (Mian and Sufi, 2011). This is the *wealth channel* which applies mainly to homeowners, but not first time buyers. Second, if house prices increase, households *can* borrow more since the value of their collateral has increased, making borrowing cheaper and easier to obtain (Campbell and Cocco, 2007). This is the *credit-constraint channel* which applies to both homeowners and first time buyers.[2] Our contribution is to show, theoretically and empirically, that if house prices increase, deposit-constrained buyers *need* to borrow more if housing and non-housing consumption are imperfect substitutes. We label this effect of house prices on mortgage demand the *housing-consumption channel* which applies to all buyers.

Disentangling the housing-consumption channel from the other channels is empirically challenging. There is generally no independent variation in the price at which a house is consumed—which governs the housing-consumption channel—and the asset price of a house—which governs the other channels. This may explain why, despite its strong intuitive appeal, the housing-consumption channel has been only implicitly addressed in the literature. For example, in the canonical model by Campbell and Cocco (2007), households can reduce their housing consumption and adjust mortgage demand when house prices increase. This allows for substitution between housing and non-housing consumption, but the paper does not specifically

[1] For recent contributions, see Jordà et al. (2016); Adelino et al. (2016); Mian et al. (2017); Di Maggio and Kermani (2017); Piskorski and Seru (2021); Verner and Gyöngyösi (2020); Bernstein (2021).

[2] The supply-driven increase in lending facilitates housing transactions, increasing house prices and strengthening the correlation between mortgage lending and house prices (Favara and Imbs, 2015).

address the impact this process has on mortgage demand. Similarly, in modelling optimal portfolio choices with housing and mortgages, Cocco (2005) allows for a preference of housing over non-housing consumption, but does not discuss its impact on mortgage choices. In the context of a model of consumption choices, Piazzesi et al. (2007) show that elasticity of substitution between housing and non-housing is important for consumption and portfolio choices but do not analyse the impact on mortgages. There are other papers that build models of mortgage choice allowing for substitution between housing and non-housing consumption. However, to our knowledge, we are the first to take on the challenge of quantifying the impact house prices have on mortgage demand via the housing-consumption channel (or simply consumption channel going forward).

The following novel elements of our study are instrumental to overcome the aforementioned empirical challenge. First, we describe a structural estimation approach from a system of mortgage demand and supply equations that allows us to separate the consumption channel from the other channels. Second, we build a unique matched property-mortgage data set in which we observe the universe of properties transacted between 2005 to 2017 in the UK, along with the transaction prices, mortgage amounts, associated interest rates, and borrower (such as age, income and whether a first-time-buyer) and property characteristics. Third, we combine the structural approach and the new data set with exogenous variation in house prices over space and time to estimate the elasticity of mortgage demand with respect to house prices that govern the consumption channel. While we can use the structure of the model to separate the consumption channel from the other channels, our structural approach requires spatio-temporal variation in property prices that is independent from mortgage demand and supply shifters (such as changes in credit market conditions) that are not included in our model. We leverage two different sources of such variation that arise from the design of the UK property tax system to build two excludable instruments.

The first instrument builds on previous research demonstrating that property transaction taxes capitalize into house prices (Best and Kleven, 2017). We exploit the reform of the UK Stamp Duty Land Tax in December 2014 which not only changed tax rates, but also replaced the tax schedule based on a step function (slab tax) with a continuous function of the seller price. Thus, the reform introduces variation in transaction tax rates, and hence house prices, that are plausibly uncorrelated with mortgage demand and supply shocks. The second instrument is based on changes in UK Council Tax, building on previous research demonstrating that property taxes capitalize into property prices (Oates, 1969). The tax amount levied on residents of each dwelling is determined based on the value of the property in 1991 (or the estimated value in 1991 if constructed later), and annual changes are applied as percentage changes in the tax amount. This results in houses with the same current market value seeing their taxes change by different amounts year-on-year (Koster and Pinchbeck, 2022). Therefore, the variation in property tax rates provides another source of variation in house prices over time that is plausibly uncorrelated with mortgage demand and supply shocks. We use both instruments together (even though either instrument is technically sufficient for identifying the consumption channel) for greater efficiency and to avoid local identification.

A distinctive feature of our paper is that we focus on households who adjust their housing consumption by moving between properties (buyers), while the existing empirical literature that links house prices and mortgage choices has focused on homeowners (Mian and Sufi, 2009). Although buyers are a small fraction of the population at any given time, most households find themselves in this category at some point in their lives, and house purchase decisions are important for long-term economic trends. Moreover, housing consumption decisions have long lasting economic and social consequences which can affect future economic decisions. We study households that can adjust their housing consumption to test the simple prediction that expenditures on housing will increase with house prices if the *static* elasticity of substitution between housing and non-housing consumption is below unity.[3] It follows that as house prices increase, buyers will borrow more unless they can finance the additional cost of housing consumption by drawing on other assets.[4]

Our central estimate of the house price elasticity of mortgage demand is 0.82. We obtain similar results in the population of mortgage buyers, and in sub-samples of first-time buyers or home movers. Our preferred specifications control for property fixed effects to keep housing consumption levels constant and location fixed effects interacted with time trends to control for changes in local market conditions (including expectations of price growth). Finally, we add flexible controls for borrower age and income to account for buyers sorting in response to changes in market conditions. This is important as it indicates that increasing house prices will translate into larger mortgages even after controlling for buyer income. This additional borrowing is driven by consumption (rather than investment) motives and adds to the

[3]There is strong empirical evidence for static elasticity of substitution to be below unity; for instance Hanushek and Quigley (1980); Attanasio and Weber (1995); Best et al. (2019), and others mentioned later in the Introduction. In contrast, Davis and Ortalo-Magné (2011) find that the rent-to-income ratio is relatively constant across US metropolitan areas, suggesting a static elasticity of substitution close to one.

[4]Buyers in the UK are deposit-constrained (Best et al., 2019), so it is unlikely that they will be able to draw upon readily available assets to increase their down payment.

household debt burden. Overall, our results show that the consumption channel is a robust feature of the data, and sub-sample results show that the channel is stronger for low-income borrowers and for smaller properties (such as terraced flats).

Our empirical results have important general-equilibrium implications that extend beyond the mortgage market since access to mortgages affects housing demand. Intuitively, there is a feedback loop between demand and supply factors in the housing and mortgage markets: higher (or expectation of higher) house prices relax credit constraints, expanding credit supply increases house prices, and rising house prices in turn increase housing and mortgage demand.[5] To quantitatively account for this simultaneity, we solve for the general equilibrium of mortgage and housing markets, allowing house prices to have an impact on mortgage supply and demand, and mortgage borrowing to have an impact on housing demand. Within this framework, we show that under a stronger consumption channel, exogenous changes in housing demand and credit supply have a larger effect on equilibrium borrowing and house prices. We then use our novel estimate of the house price elasticity of mortgage demand, a set of canonical parameter values borrowed from the literature, and exact hat algebra to switch off the consumption channel in a counterfactual equilibrium. We find that mortgage borrowing would have increased by 50% less over the past 30 years and house price growth would have been 31% lower. Consequentially, loan-to-income ratios would have decreased. This counterfactual substantiates that the consumption channel is quantitatively relevant.

While our key contribution is to quantify the consumption channel, we also make a further contribution to an issue relevant to both finance and urban economics: the degree of substitutability between housing and non-housing consumption. While micro-econometric evidence points to a static elasticity of substitution of less than one (Pakoš, 2011; Davidoff and Yoshida, 2013; Albouy, 2015; Waxman et al., 2020), other research points to expenditure shares that are approximately constant across geographies, suggesting a static elasticity of substitution of closer to one (Davis and Ortalo-Magné, 2011). Our contribution is to show that across regions and individuals in the UK, the static elasticity of substitution is about 0.7. This has important consequences for welfare effects of increasing house prices and their effect on mortgage borrowing. While the wealth and credit-constraint channels are associated with positive welfare effects, the housing consumption channel entails higher household indebtedness and leverage (and the negative effects these portend for economic and financial stability) in response to higher house prices, irrespective of the source

[5] This effect will be stronger when housing supply is inelastic and cannot adjust to the price increases caused by more credit supply. In most densely populated cities, housing supply is inelastic.

(such as when house prices may deviate from fundamentals because of diagnostic expectations, as in Bordalo et al. (2021) and Chodorow-Reich et al. (2024)) driving mortgage demand. Furthermore, we make a technical contribution by taking our novel empirical strategy to the data. We combine a simple structural estimation with a strong identification strategy which contributes to the recent trend of reconciling these two approaches (Ahlfeldt et al., 2015; Nakamura and Steinsson, 2018; Galiani and Pantano, 2021). In doing so, we also contribute to another important trend in the economic literature of using micro data to find evidence (low elasticity of substitution between housing and non-housing consumption) relevant to macroeconomic models (Campbell and Cocco, 2007; Kaplan and Violante, 2018; Beraja et al., 2019).

The remainder of the paper is structured as follows. Section 2 provides stylized facts that motivate our empirical analyses. Section 3 introduces the various channels through which house prices impact on mortgage borrowing theoretically. Section 4 develops our empirical strategy, summarizes our data and presents the results. Section 5 presents our counterfactual exercises. Section 6 concludes.

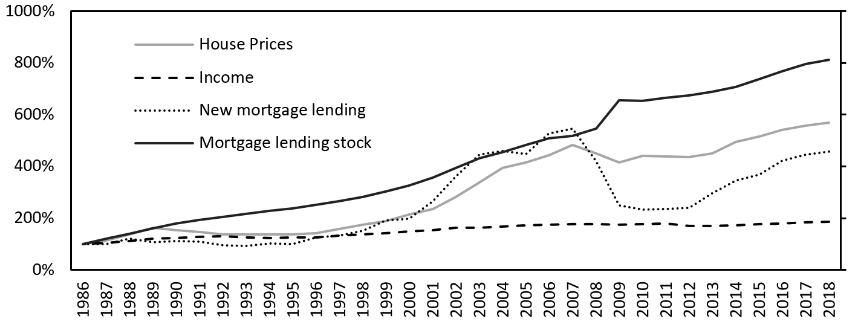
2 Stylized facts

Figure 1 shows that since 1986, mortgage lending increased by almost 700%, even exceeding house price growth of 500% over that period. At the same time, income, at less than 100%, has grown considerably slower. New mortgage lending is also correlated with house prices over time.[6] Figure 1 shows the co-movement of mortgage lending and house prices that is typically cited to motivate research into how house prices determine mortgage demand.

Figure 1 also shows that loan-to-income ratios (LTI) have increased substantially over time, while loan-to-value ratios (LTV) have remained stable. The traditional explanation is that increasing house prices generate wealth which homeowners extract from housing equity to finance non-housing consumption (Campbell and Cocco, 2007). In Figure 2, we focus exclusively on buyers and show that the trends in LTI and LTV in the market (left panel) and for first-time buyers (right) are similar. Given that first-time buyers cannot withdraw equity, it is difficult to explain the increase in LTI by a price-induced change in wealth. Indeed, the Financial Conduct Authority's (FCA) data show that between 2007 and 2019 new lending attributable to equity withdrawal decreased from 5.6% to 3.26% of total new lending.

[6] Note that during the financial crisis of 2008/09 the stock of mortgage lending increased while new lending decreased. The increase in the stock of lending is due to a decrease in repayments of

Figure 1: House price and mortgage lending trends in the UK since 1986

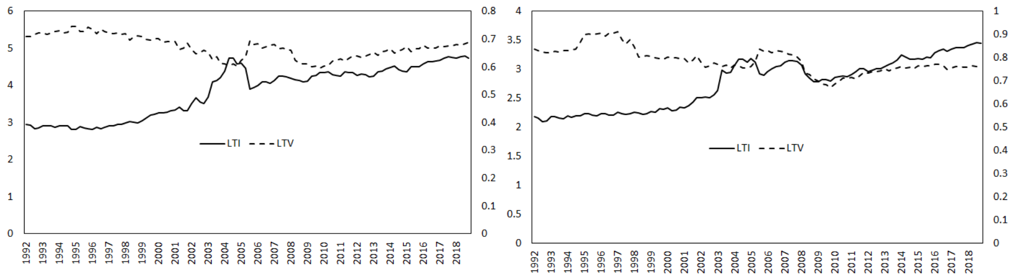


The data is indexed to the value in 1986 as 100. Data is from the Bank of England and the Office for National Statistics.

Figure 2: LTI and LTV ratios in the UK since 1992

(a) All buyers

(b) First time buyers only



The figure shows average values of loan-to-income (LTI) and loan-to-value (LTV) ratios of mortgages issued in the UK over time. The vertical axis in the left panel shows LTI ratios; the vertical axis on the right shows LTV ratios. Source: ONS dataset: House Prices: Simple Averages.

The literature offers two other explanations that rationalize the combination of increasing LTI and stagnating LTV ratios for buyers. First, lower lending standards increase mortgage borrowing and house prices (Mian and Sufi, 2011). Second, higher house prices reduce credit constraints, which leads to higher mortgage borrowing (Campbell and Cocco, 2007).

In this paper, we focus on a simpler explanation; high prices force price-insensitive and deposit-constrained buyers to borrow more to finance housing consumption. This price-insensitivity is easily documented by correlating the share of housing consumption relative to non-housing consumption with the mix-adjusted unit price of housing in Figure 3. As the price of housing increases, households do spend a greater share of their income on housing. The implication is that when buying a more expensive home, they will borrow more. Theoretically, it is also possible that more expensive houses can be financed from savings rather than additional borrow-

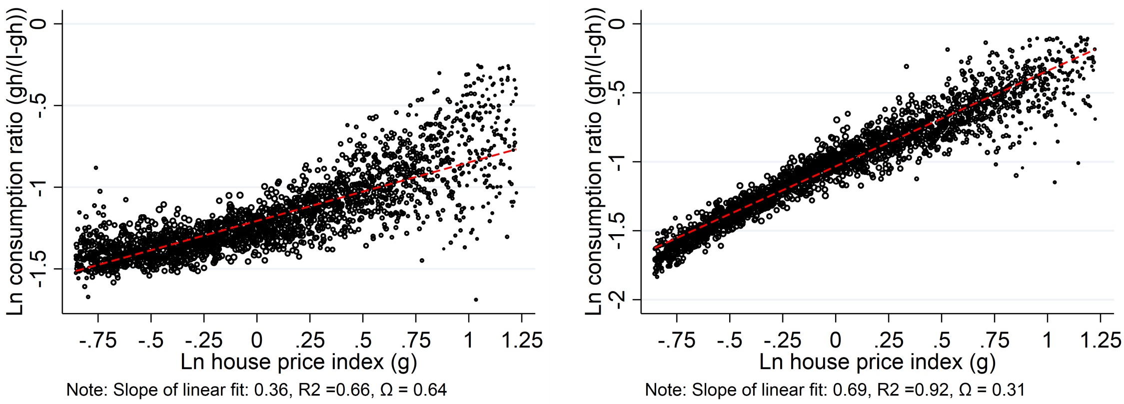
existing loans.

ing. However, as demonstrated by Best and Kleven (2017), deposit constraints are very important for UK buyers.

As shown in Appendix Section A.2, it is straightforward to derive the reduced-form relationship shown in Figure 3 from theory. Accordingly, the positive slope documented in Figure 3 corresponds to $1-\sigma$, with σ being the static elasticity of substitution between housing and non-housing consumption.[7] We substantiate the stylized fact that $\sigma < 1$ in a sequence of regressions that use different measures of housing costs and control for location and time fixed effects in Appendix Section A.2. The results confirm that while housing expenditure in the US are relatively constant across metropolitan areas (Davis and Ortalo-Magné, 2011), there is more variation at a finer geographic scale, at least in the UK. Thus, it seems unlikely that households in the UK fully offset increases in house prices by reducing housing consumption. The resulting pressure on the household budget is central to the theoretical motivation of a consumption channel in mortgage demand.

Figure 3: Static elasticity of substitution

(a) Housing cost: Mean rent (b) Housing cost: Annualized house price



The figure is based on pooled data at the postcode sector-year level covering the period 2011-2018. Data are aggregated to bins defined for 0.001-log-points of the house price index. Marker sizes are proportionate to the number of observations within a bin. Linear fits are weighted by observations within a bin. Data set is trimmed to the inter-decile range in all variables. Consumption ratio is the ratio of housing consumption (gh) over non-housing consumption ($I-gh$), where the latter is measured as the difference between gross household income I and housing cost gh. Micro-foundations for the inference of the static elasticity of substitution σ are provided in Appendix Section A.2. House price index (g) is a mix-adjusted hedonic index based on the UK land registry data which covers the universe of transactions. Income data are from the ONS and rent data are from Zoopla provided by the Urban Big Data Centre. Annualized house price is the mean house price as recorded in the land registry data, annualized for an infinite horizon at a discount rate of 5%.

[7] We define the *the static elasticity of substitution* as an elasticity of substitution between housing and non housing consumption in a static model.

3 Theoretical framework

In this section, we develop the economic intuition for a new channel in mortgage demand for which we will provide novel evidence in the subsequent sections: The *housing-consumption channel*. In order to distinguish our contribution, we also discuss alternative channels in mortgage demand such as the *wealth channel* or the *credit-constraint channel* that have been identified in the literature. For the interested reader, we substantiate the intuition behind the consumption channel within a simple static model in Appendix Section A.1.

In order to understand our contribution, it is important to acknowledge that housing is an illiquid and indivisible asset; so the effect of a change in its price differs between those who stay in their homes and those who buy a new home. The literature has mostly focused on existing homeowners. For them, house price movements trigger changes in mortgage demand because they determine their illiquid wealth. This wealth can only be turned into consumption by borrowing against it. In contrast, we focus on the housing-consumption decision of buyers, to whom a change in house prices means a change in the relative desirability and affordability of housing and non-housing consumption goods.[8]

3.1 Credit demand

House prices directly affect mortgage demand through changes in a) the cost of housing consumption and b) household wealth. The consumption effect arises from changes in prices at which houses can be purchased (buyer price). Conditional on the buyer price, the wealth effect is determined by the price at which a house can be sold (seller price).

Decisions of home owners who move are affected by the seller price of the house they sell as well as by the buyer price of the house they buy. We make this distinction to emphasize that we focus on independent changes in prices of purchased houses. Conceptually, this can be represented by a buyer who sells a house in a market where seller prices are not correlated to seller prices of their destination market (e.g. international moves), or a buyer who has already agreed the sale price of their current residence and is in the market to buy a new house. Empirically, this condition could be difficult to satisfy for movers but not first time buyers — which motivates our

[8]For simplicity, we assume in our theoretical analysis that decisions to buy are motivated by life events (such as changing jobs) and exogenous to marginal changes in the housing market. Although in the UK this assumption is not unrealistic, our empirical strategy allows us to control for the fact that rising prices may affect characteristics of the buyers by adding controls for their income and age.

choice to compare the results for the two groups in the empirical part of the paper.

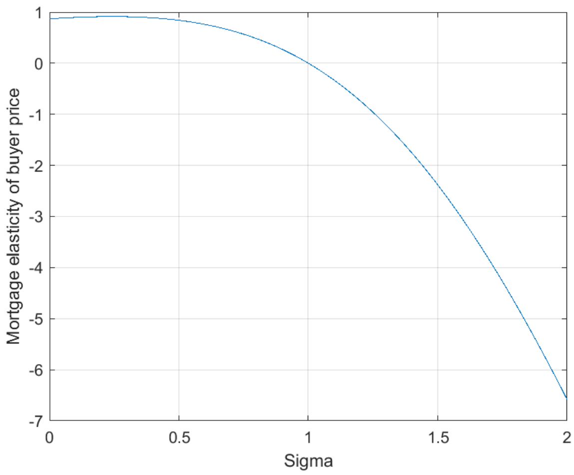
3.1.1 Housing-consumption channel

When consumption levels can be adjusted, changes in consumer prices affect consumption patterns in a way that is determined by the elasticity of substitution. An obvious example to consider in the context of the housing market are renters who are purchasing a house, but the logic applies to all households who adjust their housing consumption (buyers). Keeping all else constant, more expensive housing consumption should reduce housing consumption, but whether the overall budget allocated to housing increases or decreases depends on the degree of substitutability of consumption between goods and periods. If demand is relatively inelastic because households find it difficult to substitute away from housing consumption in the contemporary period, the budget for housing consumption will increase as house prices rise. This will increase credit demand unless households bear the additional cost entirely out of equity. Hence, our central theoretical argument is that a low elasticity of substitution lends itself to a positive buyer price elasticity of mortgage demand.

To quantitatively evaluate how the elasticity of substitution between housing and non-housing consumption moderates the relationship between mortgage demand and house prices, we develop a simple static model in Appendix Section A.1. In Figure 4, we use this model under an arguably canonical parametrization to plot how the buyer price elasticity of mortgage demand, ω, varies in the elasticity of substitution, σ. Indeed, it turns out that $\omega > 0 \; \forall \; \sigma < 1$. Intuitively, a buyer household, with a given level of savings available for a deposit, *ceteris paribus*, will wish to borrow more if house prices rise because housing consumption decreases less-than-proportionately in house prices. At $\sigma = 1$, the expenditure on housing is insensitive to the buyer price, so that mortgage demand is constant and $\omega = 0$. At $\sigma > 1$, households find it so easy to substitute away from housing consumption that the expenditure on housing and mortgage demand decrease as house prices increase, resulting in $\omega < 0$.

The magnitude of the buyer price elasticity of mortgage demand naturally depends on the parametrization. In our case, it decreases (in absolute terms) in the housing expenditure share and increases in the equity share. However, the central qualitative prediction of our theoretical framework is insensitive to the choice of parameter values: If housing and non-housing goods are imperfect substitutes, increases in house prices lead to greater mortgage demand via a consumption channel.

Figure 4: The housing-consumption channel in mortgage demand



The figure uses the theoretical framework in Appendix Section A.1 to express the buyer price elasticity of mortgage demand, ω (derived in Eq. (A5)) as a function of the static elasticity of substitution between housing and non-housing consumption, σ. All other parameters are held constant. I is set to 500, A to 10, g to 10, r to 0.05 and α to 0.3. Note that these values are for illustration only and have no interpretation. While they determine the shape of the line in the figure and the values on the vertical axis, they do not alter its key feature; the buyer price elasticity of mortgage demand is positive for $\sigma < 1$ and negative for $\sigma > 1$.

3.1.2 Wealth channel

In a simple world where everyone rents from absentee landlords, housing is purely a consumption good. For owner-occupiers, housing is also an investment good. In fact, their home is often the single most important asset and its seller price determines the amount it adds to the wealth of the owner. Intuitively, greater wealth, in general terms, should be associated with greater consumption. Indeed, early research into the relationship between house prices and non-housing consumption documented a positive correlation (Bostic et al., 2009). However, the optimal allocation of greater housing wealth to housing and non-housing consumption is not straightforward (Cocco, 2005). In fact, it is a complex optimization problem that needs to consider consumption characteristics of housing, weigh them against non-housing consumption, and take into account liquidity and borrowing constraints. Importantly, how homeowners access additional housing wealth to adjust consumption patterns depends on whether they are moving between homes or staying in their current residences. While the wealth of first-time buyers is not affected by historical increases in prices, they could shape their expectations of wealth growth and affect their current choices. We therefore consider the *wealth channel* as a general mechanism that applies differently to these distinct groups.

The simplest case is that of first-time buyers. They have no housing wealth before they buy a house so there is no direct wealth effect on their mortgage demand.

However, once they buy, they expect their equity to change in value over time. Therefore, they may want to borrow more if they expect house prices to rise. If price growth expectations are affected by recent changes in house prices (Glaeser and Nathanson, 2017), there will be a relationship between mortgage demand of first-time buyers and recent changes in seller house prices driven by an "expected" wealth channel. In the absence of a consensus in the literature, we take the liberty of naming this mechanism the *savings channel* as a sub-channel to the wealth channel that applies to all borrowers even if their current wealth is not affected by house prices.

For buyers who move between homes, the savings channel works in the same way. The only difference is that the seller price of the old home provides an additional channel through which house prices can affect consumption and mortgage demand since higher prices lead to higher net wealth of moving households (the *cash channel*). The impact of this channel on mortgage demand, conditional on the same level of housing consumption, is likely to be negative as wealthier households tend to use lower LTVs. Since even our unusually rich data set does not allow us to track borrowers over time, we abstract from this channel in our empirical analysis by assuming that seller price changes of the old and the new home are uncorrelated. Since this is a strong assumption, we acknowledge that first-time buyers may provide a better opportunity to identify the consumption channel.

Owners who do not move are affected by the savings channel as they can choose to adjust their mortgages based on their beliefs about future house price growth, but not the cash channel. However, stayers can still react to the impact changing prices have on their current wealth. They can use their extra housing wealth to increase their non-housing consumption and investment by borrowing additional funds (Browning et al., 2013). This *liquidity channel* has well-documented implications for the mortgage credit market (Mian and Sufi, 2009). We view it as a sub-channel of the wealth channel that applies exclusively to stayers. Indeed, the relationship between house prices and demand for credit has become one of the key economic issues after the financial crisis of 2008-09. The seminal work of Mian and Sufi (2011) links increases in house prices to higher mortgage demand as households extract equity from their houses to finance (non-housing) consumption. Our contribution complements this literature in that we provide robust evidence for the consumption channel.

3.2 Credit supply

We now turn to changes in house prices that affect mortgage borrowing through their impact on credit supply faced by households. This effect occurs as seller prices affect the value of collateral which determines the cost and availability of credit (since LTVs are based on the seller price). Here, the situation is simpler than on the demand side as first-time buyers, movers and stayers face the same supply conditions.

3.2.1 Credit-constraint (collateral) channel

Recent research finds that the increase in mortgage lending in response to an increase in house prices exceeds the amount predicted the liquidity channel (Cloyne et al., 2019). Literature attributes this finding to the fact that housing also plays an important role in alleviating borrowing constraints (Campbell and Cocco, 2007). Credit-constrained households can use housing wealth as collateral. If the value of collateral increases, the owner can borrow more at the same mortgage rate to reallocate consumption and move towards an unconstrained optimum. In this scenario, lending increases not only because households become wealthier but also because they have better access to more affordable credit. This is the credit-constraint channel (also known as the collateral channel). We view it as originating from the supply side since it genuinely depends on how mortgage suppliers respond to increasing housing values.

This effect is easy to illustrate from the lender's perspective. If prices of mortgages increase, profit-maximizing banks will increase the supply of mortgage credit. Indeed, based on conditional estimates of interest rates from Best et al. (2019), we infer that the interest rate elasticity of mortgage supply is around 0.3. (see Appendix A.4 for details). In the UK mortgage market, there are no strict loan-to-value restrictions (although LTVs of more than 95% are rare), but mortgage prices are determined by this ratio. A corollary of this is that the higher the value of the collateral, the lower the interest rate a household has to pay for the same loan. Therefore, increasing the seller price increases credit supply and, eventually, the equilibrium quantity of loans.

3.3 Empirical implications

We provide a simple typology of the channels through which house prices affect mortgage lending in Table 1. Importantly, we note two key features of those channels that are important for our empirical strategy and help us clarify our contribution. First, the impact of the consumption channel has not been quantified. This is a significant gap in the literature since, unlike for the other channels, greater lending driven by the consumption channel is associated with lower household welfare. Second, not all channels are relevant at all times. We will exploit this feature in our strategy as we will focus only on households that can adjust their housing consumption - buyers.

Table 1: House price effects on mortgage lending: Channels

Main channel	Sub-channel	Origin	Occurrence	Impact on borrowing	Relevant house
Consumption	-	Demand	Moving	Unknown	New
Wealth	Savings	Demand	Always	Unknown	New/current
Wealth	Cash	Demand	Moving	Negative	Old
Wealth	Liquidity	Demand	Staying	Positive	Current
Credit constraint	-	Supply	Always	Positive	New/current

Table shows a summary of the main and sub-channels discussed in Section 3. Origin refers to whether the house price effect on mortgage lending originates from the demand side (borrowers) or supply side (lenders). Occurrence refers to whether households are moving between or staying in their homes. Impact summarizes the evidence on the direction of the effect of an increase in house prices on mortgage lending. Buyer price is the price at which the house is purchased. Seller price is the price at which the house is sold. Buyer and seller prices are not the same due to transaction costs and taxes. New house is the property a home-mover is moving into; old house is the property a buyer is moving out of. Current is the property a stayer is remaining in.

4 Empirical analysis

In this section, we develop a structural estimation strategy that follows from a system of mortgage demand and supply equations that are motivated by the theoretical framework in Section 3.

4.1 Structural equation system

We describe mortgage demand, L_D, as a standard multiplicative exponential function that covers the factors discussed in Section 3.1.

$$L_D = \tilde{\mathcal{D}} r^{\theta} g^{\omega} \bar{n}^{\phi}, \tag{1}$$

where r is the price of a mortgage, g is the buyer price of a house, $\bar{n}$ is the expected future sale value of the house, and $\tilde{\mathcal{D}}$ is an arbitrary mortgage demand shifter. $\omega, \phi > 0, \theta < 0$ are parameters. Our object of interest is the buyer price elasticity of mortgage demand, ω, which governs the consumption channel. As illustrated in Figure 4, ω is inversely related to the static elasticity substitution between housing and non-housing consumption, σ. We expect $\omega = 0$ if $\sigma = 1$ and $\omega > 0$ if $\sigma < 1$. Parameter ϕ governs the savings channel. There is no liquidity channel because we focus on buyers and there is no cash channel because we assume that the price of the new house is uncorrelated to the price of the old house (or focus on first time buyers).

Similarly, we characterize mortgage supply, L_S, as multiplicative exponential function that covers the factors discussed in Section 3.2:

$$L_S = \tilde{\mathcal{S}} r^{\rho} n^{\zeta}, \tag{2}$$

where r is defined as above, n is the seller price of the house and $\tilde{\mathcal{S}}$ is an arbitrary mortgage supply shifter. $\rho > 0$ and $\zeta > 0$ are parameters, with ζ governing the credit constraint channel. We view observed quantities and prices of mortgages as equilibrium outcomes that clear the market. Hence, solving Eq. (2) for r, substituting into Eq. (1), and taking logs yields:

$$\ln L = \underbrace{\omega \frac{\rho}{\rho - \theta} \ln g}_{\substack{\text{consumption} \\ \text{channel}}} - \underbrace{\varsigma \frac{\theta}{\rho - \theta} \ln n}_{\substack{\text{cred.-constraint} \\ \text{channel}}} + \underbrace{\phi \frac{\rho}{\rho - \theta} \ln \bar{n}}_{\substack{\text{wealth (savings)} \\ \text{channel}}} + \underbrace{\frac{\rho}{\rho - \theta} \mathcal{D} - \frac{\theta}{\rho - \theta} \mathcal{S}}_{\substack{\text{other} \\ \text{channels}}} \tag{3}$$

where $\mathcal{D} = \ln \tilde{\mathcal{D}}$ and $\mathcal{S} = \ln \tilde{\mathcal{S}}$.

Equation (3) lays out how equilibrium mortgage lending is determined by the consumption channel governed by the buyer price elasticity ω, the savings channel governed by the seller price elasticity ϕ, and the credit constraint channel governed by the seller price elasticity of mortgage supply ζ. All channels are moderated by the mortgage price elasticities of demand (θ) and supply (ρ).

In practice, the buyer and seller price differ because of the wedge introduced by the property transaction tax τ so that:

$$\ln g = \ln n + \ln(1 + \tau) \tag{4}$$

For the empirical analysis it is useful to substitute Eq. (4) into Eq. (3) to obtain the following mortgage quantity equation:

$$\ln L = \omega \frac{\rho}{\rho - \theta} \ln (1 + \tau) + \frac{\rho\omega - \theta\varsigma}{\rho - \theta} \ln n + \phi \frac{\rho}{\rho - \theta} \ln \bar{n} + \frac{\rho}{\rho - \theta} \mathcal{D} - \frac{\theta}{\rho - \theta} \mathcal{S} \tag{5}$$

Similarly, we can use Eqs. (1), (2), and (4) to obtain the following mortgage price equation:

$$\ln r = \frac{\omega}{\rho - \theta} \ln (1 + \tau) + \frac{\omega - \varsigma}{\rho - \theta} \ln\ n + \frac{\phi}{\rho - \theta} \ln\ \bar{n} + \frac{1}{\rho - \theta} \mathcal{D} - \frac{1}{\rho - \theta} \mathcal{S} \tag{6}$$

4.2 Structural estimation

To derive our structural estimation approach, we first parametrize the shifters of mortgage demand and supply for a buyer $i \in I$ of property $j \in J$ in neighbourhood $k \in K$ at period $t \in T$:

$$\mathcal{D}_{i,j,k,t} = \mathbf{X_i'b_D} + \mu_j^D + \eta_{k,t}^D + n_{j,t=2013}\mathbf{c_D'} + n_{j,t=1991}\mathbf{d_D'} + \epsilon_{i,j,k,t}^D \tag{7}$$

$$\mathcal{S}_{i,j,k,t} = \mathbf{X_i'b_S} + \mu_j^S + \eta_{k,t}^S + n_{j,t=2013}\mathbf{c_S'} + n_{j,t=1991}\mathbf{d_S'} + \epsilon_{i,j,k,t}^S \tag{8}$$

$\mathbf{X_i}$ is a column vector of buyer characteristics, $\{\mathbf{b_D}, \mathbf{b_S}\}$ are column vectors of parameters of the same dimensions as $\mathbf{X_i}$, $\{\mu_j^D, \mu_j^S, \eta_{k,t}^D, \eta_{k,t}^S\}$ are property and neighbourhood-period fixed effects and $\{\epsilon_{i,j,k,t}^D, \epsilon_{i,j,k,t}^S\}$ are residual terms. We also include controls for property value bands based on values in 2013 and (separately) in 1991 interacted with a time trend and a corresponding $T \times 1$ vector of parameters $\{\mathbf{c_D}, \mathbf{c_S}\}$ and $\{\mathbf{d_D}, \mathbf{d_S}\}$ respectively. These are necessary to operationalise our identification strategy explained below.

Let's define the the following deterministic components of mortgage quantities and prices:

$$\mathcal{L}_{i,j,k,t} = \ln L_{i,j,k,t} - \mathbf{X_i'b_L} - \mu_j^L - \eta_{k,t}^L - n_{j,t=2013}\mathbf{c_L'} - n_{j,t=1991}\mathbf{d_L'}, \tag{9}$$

where $\mathbf{b_L} = \frac{\rho}{\rho-\theta}\mathbf{b_D} - \frac{\theta}{\rho-\theta}\mathbf{b_S}$, $\mathbf{c_L} = \frac{\rho}{\rho-\theta}\mathbf{c_D} - \frac{\theta}{\rho-\theta}\mathbf{c_S}$, $\mathbf{d_L} = \frac{\rho}{\rho-\theta}\mathbf{d_D} - \frac{\theta}{\rho-\theta}\mathbf{d_S}$, $\mu_j^L = \frac{\rho}{\rho-\theta}\mu_j^D - \frac{\theta}{\rho-\theta}\mu_j^S$, $\eta_{k,t}^L = \frac{\rho}{\rho-\theta}\eta_{k,t}^D - \frac{\theta}{\rho-\theta}\eta_{k,t}^S$.

$$\mathcal{R}_{i,j,k,t} = r_{i,j,k,t} - \mathbf{X_i'b_r} - \mu_j^r - \eta_{k,t}^r - n_{j,t=2013}\mathbf{c_r'} - n_{j,t=1991}\mathbf{d_r'}, \tag{10}$$

where $\mathbf{b_r} = \frac{1}{\rho-\theta}\mathbf{b}_S - \frac{1}{\rho-\theta}\mathbf{b_D}$, $\mathbf{c_r} = \frac{1}{\rho-\theta}\mathbf{c}_S - \frac{1}{\rho-\theta}\mathbf{c_D}$, $\mathbf{d_r} = \frac{1}{\rho-\theta}\mathbf{d}_S - \frac{1}{\rho-\theta}\mathbf{d_D}$, $\mu_j^r = \frac{1}{\rho-\theta}\mu_j^s - \frac{1}{\rho-\theta}\mu_j^D$, $\eta_{k,t}^r = \frac{1}{\rho-\theta}\eta_{k,t}^S - \frac{1}{\rho-\theta}\eta_{k,t}^D$. Note that these deterministic components include expectations of the future sales value $\bar{n}$ that are area-specific and change over time (through the area trend) and are property-specific and do not change over time (thorough the property fixed effect). Since most households form expectations based on recently observed price trends in their area or social network (Kuchler et al., 2023), we expect that these will be correlated across houses in the same location and captured by these fixed effects.

Using Eqs. (7), (5), and (10) as well as Eqs. (8), (6), and (9), we obtain the following structural residuals:

$$\epsilon^L_{i,j,k,t} = \frac{\rho}{\rho-\theta}\epsilon^D_{i,j,k,t} - \frac{\theta}{\rho-\theta}\epsilon^S_{i,j,k,t} \tag{11}$$

$$\epsilon^r_{i,j,k,t} = \frac{1}{\rho-\theta}\epsilon^S_{i,j,k,t} - \frac{1}{\rho-\theta}\epsilon^D_{i,j,k,t}, \tag{12}$$

where $\ln L_{i,j,k,t} - \omega\frac{\rho}{\rho-\theta}\ln(1+\tau) - \frac{\rho\omega-\theta\varsigma}{\rho-\theta}\ln n - \phi\frac{\rho}{\rho-\theta}\ln\bar{n} = \mathcal{L}_{i,j,k,t} + \epsilon^L_{i,j,k,t}$ and $\ln r_{i,j,k,t} - \frac{\omega}{\rho-\theta}\ln(1+\tau) - \frac{\omega-\varsigma}{\rho-\theta}\ln\ n - \frac{\phi}{\rho-\theta}\ln\ \bar{n} = \mathcal{R}_{i,j,k,t} + \epsilon^r_{i,j,k,t}$.

To identify our parameters of interest, we can either assume orthogonality of instruments with the structural quantity residual, $\epsilon^L_{i,j,k,t}$, the structural price residual, $\epsilon^r_{i,j,k,t}$, or both. Formally, we assume:

$$\mathbb{E}(\mathbf{Z_{i,j,k,t}}\epsilon^L_{i,j,k,t}) = 0 \tag{13}$$

$$\mathbb{E}(\mathbf{Z_{i,j,k,t}}\epsilon^r_{i,j,k,t}) = 0, \tag{14}$$

where $\mathbf{Z_{i,j,k,t}}$ is column vector of instrumental variables. Using Eqs. (7), (5), and (10) as well as Eqs. (8), (6), and (9), and assuming that the deterministic components capture the effect of $\bar{n}$, we obtain the following moment conditions.

$$\mathbb{E}\left(\mathbf{Z_{i,j,k,t}}\left[\mathcal{L}_{i,j,k,t} - \omega\frac{\rho}{\rho-\theta}\ln(1+\tau) - \frac{\rho\omega-\theta\varsigma}{\rho-\theta}\ln n\right]\right) = 0 \tag{15}$$

$$\mathbb{E}\left(\mathbf{Z_{i,j,k,t}}\left[\mathcal{R}_{i,j,k,t} - \frac{\omega}{\rho-\theta}\ln(1+\tau) - \frac{\omega-\varsigma}{\rho-\theta}\ln\ n\right]\right) = 0 \tag{16}$$

We take these moment conditions to the data using a GMM estimator and a grid search. To obtain $\mathcal{L}$ and $\mathcal{R}$, we residualize L and r using regressions against the deterministic components in Eqs. (10) and (9). We estimate the key parameter of interest ω for given values of $\{\theta, \rho, \zeta\}$ as described below. We take the interest rate elasticity of mortgage demand $\theta = -0.5$ from Best et al. (2019). Since mortgage interest rates depend primarily on LTVs, we estimate the interest rate elasticity of mortgage supply $\rho = 0.3$ based on the observed relationship between mortgage interest rates and loan-to-value ratios (see Appendix A.4 for details). We assume the seller price elasticity of mortgage supply $\zeta = 1$ since, in the UK, the supply curve faced by households is determined by LTVs, and hence supply changes proportionately to the seller price. While this may not be true at the macro level over the long term (for example because banks may face funding limits), it is a good reflection of the situation faced by marginal households in our data.

To account for the uncertainty that surrounds the set parameter values, we embed the GMM estimation into a Monte Carlo procedure in which we draw the set values from distributions. Previewing our results, the key insight is that our estimates of ω can be viewed as statistically significant at conventional levels, even if we acknowledge significant uncertainty in the set parameter values. We refer the interested reader to Appendix Section A.6.5 for details.

As we discuss in the next section, we have two excludable instruments for $\{\tau, n\}$ that we can use in our moment conditions in Eqs. (15) and (16). Taking values of $\{\theta, \rho, \zeta\}$ as given, there are various ways in which we can combine our excludable instruments with these moment conditions to estimate ω. First, we can exploit the structure of each of the two equations and estimate Eq. (15) and Eq. (16) separately giving us approaches (a) and (b). Second, we can estimate them simultaneously and exploit the additional condition that ω has to be the same in both which we refer to as approach (c). However, from an inspection of the structural residuals and the moment conditions it is immediate that successful identifications hinges on the availability of instruments that are uncorrelated with mortgage demand and supply shifters, conditional on observable buyer characteristics, arbitrary neighbourhood trends and time-invariant property characteristics, and property-price-level-specific trends. To identify ω, we can instrument for the seller price n (approach i), the tax rate τ (approach ii), or both (approach iii). In total, we have nine possible ways of identifying ω using different combinations of equations ((a) - (c)) and instruments ((i) - (iii)).

4.3 Instruments

We identify our key parameter of interest from two variables that are themselves equilibrium outcomes and are potentially determined by the same (unobserved) factors that determine mortgage demand and supply: the the seller price n and the property transaction tax rate τ (which depends on n). Because n and τ are not valid included instruments, we use two excluded instruments in $\mathbf{Z}$ that satisfy two requirements. First, both instruments are plausibly uncorrelated with the structural residuals since they exploit policy-induced exogenous variation. Second, our instruments are highly correlated to the key variable we instrument them with.

4.3.1 Transaction tax instrument

Our instrument for the transaction tax rate exploits the UK stamp duty reform that became effective in December 2014. Stamp duty is a tax on transactions of assets and the amount due is based on the value of the transaction. In 2014, the reform changed both tax rates and the way in which those rates were applied from a slab tax schedule to a tax schedule with progressive steps. To describe the instrument, it is useful to consider a time-varying transaction tax schedule, H_t, that maps the seller price $n_{j,t}$ to a transaction tax rate $\tau_{j,t} = H_t(n_{j,t})$. Our instrument for $\ln(1+\tau_j)$ then takes the form:

$$\ln(1 + \widetilde{\tau_{j,t}}) = \ln(1 + H_t(\hat{n}_{j,t=2013})), \tag{17}$$

where $\hat{n}_{j,t=2013}$ is the asset value in 2013 as predicted by a repeat-sales index.[9] Intuitively, our instrument restricts the identifying variation to stem solely from the change in the tax schedule. The choice of $t = 2013$, the year before the tax reform was implemented, avoids the potential endogeneity problem that post-reform prices are affected by the tax reform.

As illustrated in panel a) of Figure 5, our instrument predicts changes in tax rates throughout the entire asset value distribution. In particular, our instrument predicts discontinuous changes at the former tax steps. We exploit this feature to ensure the validity of the instrument by controlling for fixed effects that we define for each combination of a quarter and a band (decile) of the predicted 2013 sales values. Conditional on this control for trends in asset values that may be correlated with 2013 asset value levels, the identifying variation originates primarily from the discontinuity in changes in tax rates at former tax steps (marked by vertical lines), strengthening the validity of the instrument.

The stamp duty has been demonstrated to be a significant determinant of property prices in the UK, suggesting that our instrument is relevant (Best and Kleven, 2017). We demonstrate the relevance of this instrument in our empirical setting in Appendix Section A.5.2.

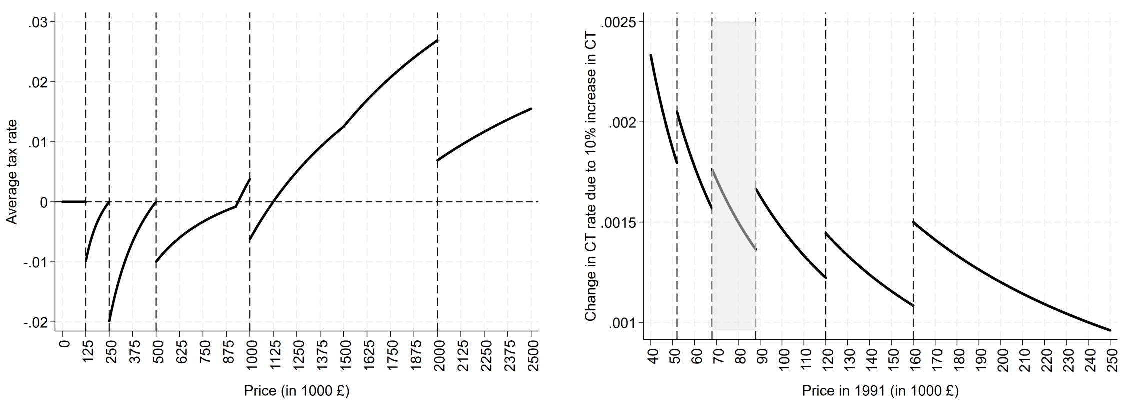
4.3.2 Seller price instrument

Our instrument for seller prices is based on changes in property taxes that can differ (in amounts and in percentage values) even between houses located next to each other that have the same asset value. The basic property tax in England and Wales is called Council Tax and is paid annually by residents of each house. It funds local authorities and essential services such as Fire and Rescue, Police, or Environmental services. There are no differences in the provision of those services within the boundary of the same local authority. The amount of tax due is based on the property's tax band assigned by a government agency. There are eight tax bands

[9] See Appendix Section A.3.2 for more details.

Figure 5: Identifying variation from tax instruments

(a) Changes in transaction tax rates (b) Changes in Council Tax rates



The figures shows the change in transaction taxes (panel (a)) and council tax (panel (b)) with house prices. In panel a): the vertical axis gives the change in the rate of Stamp Duty Land Tax due to the reform in 2014. The horizontal axis gives the price of the property. In panel b): the vertical axis gives the change in the tax rate (Council Tax divided by the price of the property) assuming that the starting band D tax is £1,200. The horizontal axis gives the value of the property in 1991. Band D applies to properties worth between £68,000 and £88,000 in 1991. We offer further clarification of how changes in Council Taxes affect property prices in appendix Table A6.

designated by letters from A to H. Allocation to a tax band is based on the value of a house in 1991, and the same banding thresholds apply countrywide.[10] Local authorities set the tax amount for band D and amounts for other bands are simply fixed shares of band D (from 67% at band A to 200% at band H). This means that when the tax amount for band D is changed, taxes change by different amounts (and percentages of property value) for houses in different bands.

To construct our instrument for seller prices, we begin by predicting the asset values in 1991 based on which we assign each house to the appropriate tax band. Combing this tax-band assignment with annual data on band D tax amounts in each local authority (from the Ministry of Housing, Communities and Local Government), we construct our instrument for $\ln n_j$ as follows:

$$\ln(1 + \widehat{CTR}_{j,K,t}) = \ln\left(1 + \frac{f(\hat{n}_{j,t=1991})}{\hat{n}_{j,t=1991}} CT^{Index}_{K,t}\right), \qquad (18)$$

where $\widehat{CTR}_{j,K,t}$ is the predicted council tax rate for a property j in local authority K at time t, f is the assignment function that maps the historic asset value $\hat{n}_{j,t=1991}$ to the tax amount due in 1991, $CT^{Index}_{K,t}$ is a local authority-year specific index that inflates the historic tax amount to the contemporary tax amount, and $\hat{n}_{j,t=1991}$ is

[10]New properties are allocated to tax-bands based on an estimated value in 1991 using local area price trends (which is in line with our approach for allocating properties to bands.

the predicted historic asset value. Intuitively, increases in $CT_{K,t}^{Index}$ amplify existing differences in tax rates in 1991 over time, generating property-specific changes in $\widehat{CTR}_{j,K,t}$ that will be negatively associated with changes in seller prices. As we show in Appendix Section A.5.1, the chosen functional form of the instrument follows directly from the assumption that the seller price is depreciated by the present value of council taxes to be paid. There, we also provide a numerical example in Table A6 to further develop the intuition.

As we illustrate in panel b) of Figure 5, an increase in the local authority-specific council tax index $CT_{K,t}^{Index}$ maps into different property-specific changes in council tax rates for properties with the same asset value, depending on their historic asset value. Notice that after we control for property and year-by-location fixed effects, the identifying variation in annual changes in council tax rates comes from the interaction of historical differences in property values and local authority trends in council taxes, exclusively. Conditional on our controls for heterogeneity in trends along the 1991 asset price distribution, the discontinuity in the changes in tax rates at the tax bands becomes the primary source of identifying variation, strengthening the validity of the instrument.

Council taxes have been demonstrated to have a significant impact on property markets in the UK, suggesting that our instrument is relevant (Koster and Pinchbeck, 2022). We demonstrate the relevance of this instrument in our empirical setting in Appendix Section A.5.2.

4.4 Data

We use property-specific data on house prices, transaction taxes, mortgage interest rates, loan size and borrower characteristics at the time of the housing transaction to implement our empirical strategy. To this end, we create a unique data set combining two large-scale micro data sets in the United Kingdom: the universe of housing transactions (with house prices and granular location and property characteristics) from the HM Land Registry and the universe of mortgage originations (PSD001, with granular mortgage and borrower characteristics) from the Financial Conduct Authority. To build our instruments, we use transaction tax and property tax schedules sourced from and the Ministry of Housing, Communities & Local Government.

We merge mortgage originations from the PSD001 to housing transactions from the Land Registry based on the transaction price, postcode and the year-quarter of the transaction reported in both datasets. This variable uniquely identifies 95% of transactions in the land registry transactions between 2005-2017, and we are able to match 37% of those to the mortgage originations data. By virtue of merging across the datasets, we include only housing transactions that are bought using a residential mortgage (i.e. excluding cash-only and Buy-to-Let transactions). As mentioned before, we obtain house prices and highly disaggregated location information from the housing transactions data, and loan value, borrower income (and therefore loan-to-income ratio), age and mortgage interest rate from the mortgage origination data. We add an additional filter to this database—we consider addresses/properties that have at least two mortgage-based transactions during 2005-2017 (we include a property fixed-effect as a part of our highly conservative estimation assumptions). We report summary statistics for the resulting 701,383 matched observations in Table 2.[11]

The average price of the housing transactions in our database is £239,038, with an average loan value of £168,523. The average borrower in our sample has an income of £54,928, and is 35 years old. The households in our sample pay a transaction tax or stamp duty of £2,795, with a substantial variation in both the total value of the stamp duty, and the stamp duty rate (as a proportion of the total house price). We also use the information in the universe of housing transactions to create house price indices at an MSOA level and use these local-area level indices to predict the house price the property would have transacted at alternate time-periods (1991 and 2013).[12]

4.5 Consumption channel parameter estimates.

Table 3 shows the baseline GMM estimates of buyer price elasticities of mortgage demand (ω) using the moment conditions outlined in Section 4.2 and the excluded instruments introduced in Section 4.3. This table shows the estimates based on our preferred approach: using the two equations (pertaining to mortgage prices and quantities) and either one of the two excluded instruments or both, and in our matched sample of properties with multiple transactions. In the table, we show the estimated value of ω while using the instrument for seller price (indicated as i), for the transaction tax (ii), and using both of them (iii). Columns (1)-(3) in Table 3 show the estimates using the full sample ranging from 0.82-0.86. We also report estimates from sub-samples involving repeat sales of a property by first-time buyers

[11] We provide further information on data construction which maps from the universe of housing transactions to our sub-sample of 701,383 observations in Appendix Section A.3.1.

[12] Stamp duty is based on the transaction price of the property and the prevailing (as on the date of the transaction) rate for calculating the duty. The tax is based on a flat rate on increasing portions of the property price. See A.3.2 for details on the construction of the house price indices.

Table 2: Summary Statistics for all transactions (2005-2017)

	mean	sd	p10	p50	p90
Price	239,038	158,573	113,500	195,000	408,000
Predicted price (2013)	228,439	158,132	103,777	187,041	390,373
Predicted price (1991)	70,186	39,341	36,656	60,408	113,003
Stamp duty	2795	5935	0	1300	9450
log(Loan value)	11.879	0.564	11.225	11.882	12.572
log(Int. rate)	-3.316	0.451	-3.917	-3.221	-2.832
log(Price)	12.236	0.516	11.640	12.181	12.919
log(1+Tax rate)	0.008	0.011	0.000	0.010	0.030
Tax instrument	0.010	0.012	0.000	0.010	0.030
Price instrument	0.010	0.009	0.002	0.005	0.023
Loan value	168,523	102,237	74,995	144,596	288,244
Loan-to-income ratio	3.28	1.32	1.94	3.32	4.48
Buyer income	54,928	37,925	24,721	45,398	92,023
Buyer age	35	9	25	33	49
Observations	701,383				

The table shows summary statistics for land registry transactions that are associated with an underlying property that is transacted at least twice between 2005-2017 through a mortgage. This sample is used for estimating the parameter governing the housing consumption channel. See Appendix Section A.3.1 for notes on dataset construction.

(columns 4-6) and home movers (columns 7-9). First-time buyers, unlike movers, are not affected by the *cash channel*.[13] We note that the results are comparable across these two disjoint sub-samples, suggesting that the *cash channel* is not substantially affecting our estimates of ω.

Together, these estimates provide confidence in both the empirical relevance of the consumption channel, and our empirical estimates of the parameter governing the same. The direction of the consumption channel effect is positive, i.e. mortgage demand increases in response to increases in the buyer price of housing. According to our theoretical evaluation summarized in Figure 4, a value of $\omega > 0$ is consistent with a static elasticity of substitution between housing and non-housing consumption of $\sigma < 1$. Hence, our estimates of ω are consistent with the positive correlation of house prices and the housing expenditure shares in Figure 3. We consider the estimate reported in column 3 (0.82) as our preferred estimate: this estimate is based on the full sample while imposing the full structure of our mortgage demand and supply framework and exploiting exogenous variation from both instruments, reducing external validity concerns due to local identification.

[13] See Section 3.1.2 for a discussion. "*Cash channel*" has an ambiguous effect on borrowing in response to a house price increase: households may use the additional housing wealth to trade up or to opt for lower leverage (richer households tend to have lower LTVs in ths UK). Since our identification strategy is based on comparing outcomes for the same property over time, "*cash channel*" is expected to go in the opposite direction of consumption channel.

Robustness. We conduct numerous robustness tests based on our baseline, preferred specification for estimating ω (i.e. the one used in column (3) of Table 3). Appendix Table A8 shows that the estimated ω is robust to the inclusion of our very granular fixed effects: we sequentially add all the fixed-effects from columns (2)-(6) without a significant change in the estimated value. Appendix Table A10 shows the value of ω estimated in sub-sample by property type (panel (a)), tenure-type (panel (b)), and borrower-type (age/income, panel (c)). We find that the consumption channel is strongest for small properties (i.e. terraced flats) vs larger properties (detached homes); however, there is no discernible difference by tenure (leasehold or freehold properties), and somewhat surprisingly, or borrower age/income. While Table 3 shows that the estimated ω is robust to including either of the two instruments, in Appendix Table A9 we study the effect of using just one of the two equations for estimation. Appendix Table A9 panel (a) shows that the estimated ω is still quantitatively and statistically significant when using the moment condition based on loan quantities. The coefficient is smaller when using just loan prices (panel (b)), but still positive and significant when applying both instruments to the full sample and the sampel of first-time-buyers.

We go beyond these robustness tests to subject our GMM estimator to a grid search and a Monte Carlo simulation. First, we take the moment conditions in Eqs. (15) and (16) to the data in a grid search over different values of ω. Results reported in Appendix Section A.6.4 confirm that the GMM estimator identifies a well-defined global minimum in the objective function. Next, we nest our GMM estimation strategy in a Monte Carlo simulation by drawing bootstrapped samples (of equal N, with replacement) and by drawing parameter values from normal distributions to capture the associated uncertainty in our estimation strategy (see Appendix Section A.6.5 for further information). We allow for a significant degree of dispersion in the drawn parameter values for $\{\theta, \zeta\}$, with a coefficient of variation of about 0.3. To be theory consistent, in each Monte Carlo simulation, we estimate ρ conditional on the drawn value of ζ and the bootstrapped sample, and then draw a value of ρ from a distribution governed by the point estimate and the standard error. Across 1,000 simulations, we obtain a sampling distribution of ω estimates with a mean of 0.82 and a standard deviation of 0.27, allowing us to comfortably reject that the consumption channel is insignificant.

Table 3: Structural estimation results of omega

	All			FTB			HM		
	i	ii	iii	i	ii	iii	i	ii	iii
ω	0.858***	0.731***	0.818***	0.876***	0.824***	0.864***	0.886***	0.814***	0.857***
	(0.0142)	(0.0205)	(0.0120)	(0.0303)	(0.0503)	(0.0270)	(0.0314)	(0.0364)	(0.0245)
Observations	701,383	701,383	701,383	139,810	139,810	139,810	244,138	244,138	244,138
CT IV	Yes		Yes	Yes		Yes	Yes		Yes
SDLT IV		Yes	Yes		Yes	Yes		Yes	Yes
Loan eq.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interst eq.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prop. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area tr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Price '91 tr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Price '13 tr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Buyer char.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lender tr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table shares GMM estimates of ω using different sub-samples, and combinations of moment conditions and instruments as shown in the column headings. 'All' refers to a sample of repeat sale properties including all buyers, 'FTB' refers to a sample of repeat sale properties bought by first time buyers, and 'Movers' refers to a sample of repeat sale properties bought by previous owners. 'CT IV' is the council-tax instrument for seller prices. 'SDLT IV' is the Stamp Duty Land Tax reform instrument for transaction tax rates. 'Loan eq.' refers to moment conditions from the mortgage quantity equation outlined in Eq. (15) and 'Interest eq.' to conditions from Eq. (16). 'Prop. FE' are property fixed effects; 'Area tr.' are MSOA fixed effects interacted with quarterly time trends; 'Buyer char.' refers to controls for borrower income, age and whether first time buyer or previous owners; 'Price '91 tr' are price bands (deciles, based on transacted prices projected to 1991) interacted with quarterly time trends; 'Price '13 tr'. are price bands (deciles, based on transacted prices projected to 2013) interacted with quarterly time trends; and 'Lender tr.' are lender dummies interacted with yearly time trends. Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$).

5 Counterfactual analysis

Prices and quantities on housing and mortgage markets are simultaneously determined. For the identification of the consumption channel in mortgage demand, we have abstracted from this simultaneity by exploiting variation in house prices that is exogenous to mortgage demand and supply. To understand the quantitative relevance of the consumption channel for aggregate outcomes in housing and mortgage markets, it is important to account for this simultaneity. Therefore, we introduce housing demand and supply equations following the same canonical log-linear structure as we have used to describe mortgage demand and supply in Section 4.2. Intuitively, we establish the reciprocal relationship between housing and mortgage markets by making housing demand a function of mortgage borrowing, in addition to mortgage borrowing being a function of the house price. Assuming market clearing on housing and mortgage markets, we obtain an exactly identified system of equations from which we can infer equilibrium prices and quantities on housing and mortgage markets for given parameter values that we have either estimated or can borrow from the literature. We can then quantitatively evaluate how the endogenous outcomes respond to exogenous changes in housing demand or mortgage supply for different values of ω, which monitors the consumption channel.

5.1 Quantitative framework

We characterize the housing market by the following demand and supply equations:

$$h_D = \tilde{\mathcal{D}}_h g^{\kappa} n^{\xi} L^{\lambda} \tag{19}$$

$$h_S = \tilde{\mathcal{S}}_h n^{\eta}, \tag{20}$$

where h^d and h^s represent housing demand and supply, L is borrowing[14], n is the seller price, $\tilde{\mathcal{D}}_h$ is a fundamental demand shifter, $\tilde{\mathcal{S}}_h$ is a fundamental supply shifter and $\{\kappa, \lambda, \xi, \eta\}$ are parameters. Consistent with our theoretical framework in Section 3, buyer prices affect housing demand via the consumption channel (monitored by κ) whereas seller prices affect housing demand via the wealth channel (monitored by ξ). Housing supply increases in the seller price at an elasticity η.

Together with the mortgage demand and supply Eqs. (1) and (2), the buyer price definition $g = (1 - \tau)n$, and the two market clearing conditions $L_D = L_S$

[14]While most papers that link credit an housing markets assume that housing demand is a function of the price of credit, in our framework, credit quantity is the main driving factor while the price of credit is an equilibrium outcome determined in the two markets.

and $H_D = H_S$, Eqs. (19) and (20) form a system of seven equations that allows us to solve for seven endogenous variables $\mathbf{W} \in \{h_D, h_S, L_D, L_S, n, g, r\}$ if structural fundamentals $\mathbf{V} \in \{\tilde{\mathcal{D}}_L, \tilde{\mathcal{S}}_L, \tilde{\mathcal{D}}_H, \tilde{\mathcal{S}}_H, \tau\}$, price expectations $\{\bar{n}\}$ and parameters $\{\theta, \omega, \phi, \rho, \zeta, \kappa, \xi, \eta\}$ are given. Following the logic of conventional *exact hat algebra* (Dekle et al., 2007), we do not have to take a specific stance on the structural fundamentals since we can express any outcome in a counterfactual, indicated by superscript c, as a function of the outcome observed in the baseline equilibrium, indicated by superscript 0, and a relative change, indicated by *hat*, $\hat{\mathbf{W}} = \frac{\mathbf{W^c}}{\mathbf{W^0}}$, that does not depend on $\mathbf{V}$. We derive the equations that map relative changes in exogenous fundamentals $\hat{\mathbf{V}}$ into relative changes in endogenous outcomes $\hat{\mathbf{W}}$ in Appendix A.7. There, we also show how to use this mapping to derive counterfactual values of the endogenous variables in the absence of a consumption channel ($\omega = 0$) as

$$\mathbf{W^{NCC}} = \exp\left(\frac{\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}}}{\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}} \ln \hat{\mathbf{W}} \right) \mathbf{W^0}, \tag{21}$$

where $\ln \hat{\mathbf{W}}$ is the log change in an outcome over an arbitrary period observed in data, $\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}$ is the partial derivative of this outcome $\mathbf{W}$ with respect to the fundamental $\mathbf{V}$ under an estimated value of ω, and $\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}}$ is the same derivative under $\omega = 0$.

5.2 Parameter values

We summarize our parameter value choices in Table 4. We use our novel estimate of parameter ω from Section 4.5 along with the values for $\{\theta, \rho, \zeta\}$ that we have already introduced in the context of the structural estimation in Section 4.2. In the baseline, we use our preferred estimate of ω from Table 3, Column All (iii).

For the housing supply price elasticity, we draw from Saiz (2010) who shows that there is substantial heterogeneity in the value of the housing supply elasticity in the US. While in many areas the elasticity is close to the canonical value of two, it is closer to one in places with tight land-use regulations. Since there is strong evidence that the UK planning system is highly restrictive (Hilber and Vermeulen, 2016), we set $\eta = 1$. We further set the price elasticity of housing demand to $\kappa = -0.5$ which is a canonical value in the literature (Hanushek and Quigley, 1980). Notice that this value implies that housing consumption decreases less than proportionate as house prices increase, which is consistent with inelastic substitution between housing and non-housing consumption implied by $\sigma < 1$ and $\omega > 0$. For the elasticity of housing demand with respect to borrowing, we choose a value of $\lambda = 0.75$ because home buyers in the UK pay three-quarters of the transaction price out of mortgages, on average (Registry, 2017). Finally, for simplicity, we assume that $\bar{n}$ is exogenous, so our counterfactual does not depend on $\{\phi, \xi\}$.

Table 4: Parameter values

Elasticity	Symbol	Value	Derivation
Interest rate elasticity of mortgage demand	θ	-0.5	Best et al. (2019)
Interest rate elasticity of mortgage supply	ρ	0.3	Estimated[a]
Seller price elasticity of mortgage supply	ς	1	Assumed[b]
Buyer price elasticity of mortgage demand	ω	0.82	Estimated[c]
Price elasticity of housing demand	κ	-0.5	Hanushek and Quigley (1980)
Price elasticity of housing supply	η	1	Saiz (2010)[d]
Elasticity of housing demand w.r.t borrowing	λ	0.75	Assumed[e]

The table shows the sources of the calibrated parameter values, which are either estimated or sourced from the literature. [a]: The supply curve is estimated from data from the Bank of England in Appendix A.4; we estimate ρ based on the observed relationship between mortgage interest rates and loan-to-value ratios. [b]: This assumption is motivated by mortgage interest rates offered by UK lenders being highly sensitive to and primarily determined by loan-to-value ratios. [c]: See Table 3 for estimation results. [d]: A unit value is estimated for highly regulated supply-inelastic areas in the US. [e]: Home buyers in the UK, on average, pay three quarters of the house price using mortgages.

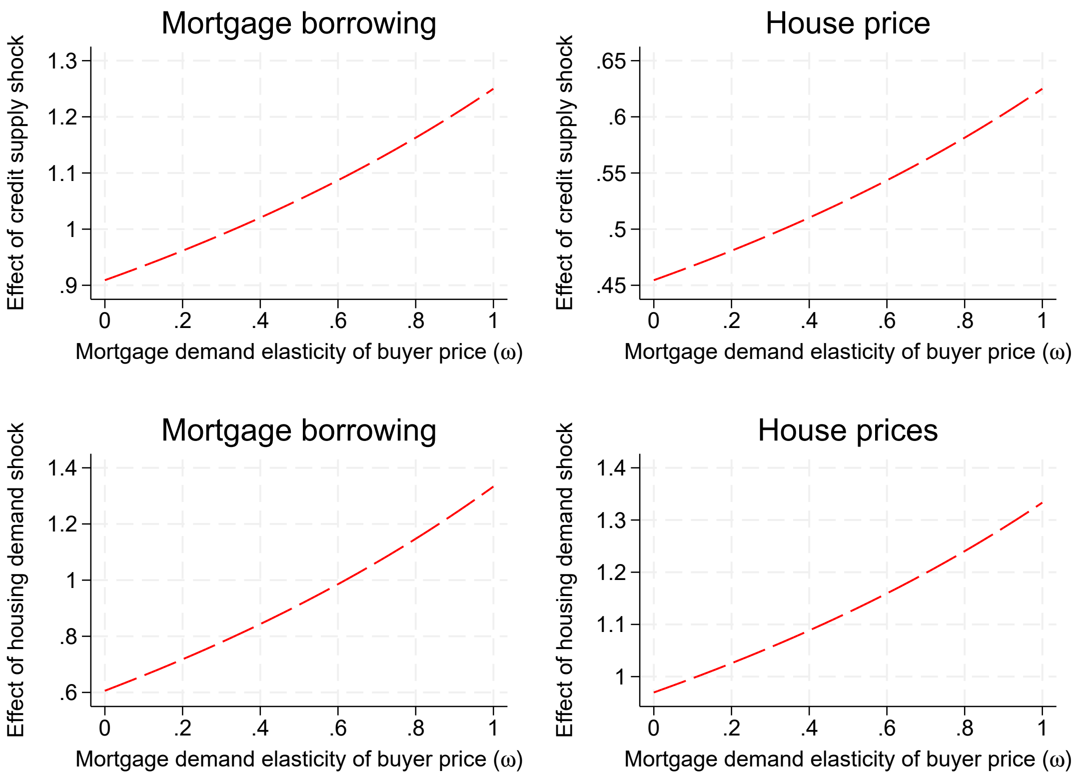
5.3 Transmission of shocks

To understand how the consumption channel monitors the transmission from a shock to an exogenous fundamental $\mathbf{V}$ to a change in an endogenous variable $\mathbf{W}$, it is useful to inspect the derivative $\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}$ under varying values of ω. In Figure 6, we use the derivatives reported in Appendix A.7.1 to illustrate how an increase in the exogenous housing demand shifter ($\tilde{\mathcal{D}_{\mathcal{H}}}$) or the exogenous credit supply shifter ($\tilde{\mathcal{S}_{\mathcal{L}}}$) affect equilibrium levels of mortgage borrowing and house prices. All variables are in logs so that the values on the y-axes can be interpreted as elasticities.

In keeping with intuition, positive shocks to housing demand and credit supply increase borrowing and house prices. This would be true even in the absence of a consumption channel in mortgage demand, i.e. if $\omega = 0$, but the effects would be significantly smaller. As an example, a positive shock to credit supply has a *direct* effect on the mortgage market; it causes a fall in interest rates and an increase in mortgage borrowing to clear the mortgage market. The additional mortgage borrowing adds to housing demand, increasing house prices. Depending on the value of ω, this increase in house price causes an *indirect* increase in mortgage borrowing through the consumption channel, which itself affects house prices. Likewise, an exogenous shock to housing demand causes a *direct* increase in house prices to clear the market. The increase in house price leads to greater mortgage demand through the consumption channel that depends on ω. Since borrowing affects housing demand, there is an *indirect* effect on housing demand and a further increase in the house price, which further adds to mortgage demand. The larger the effect of the consumption channel—holding the effect of the wealth channel constant—the larger the *indirect* effects and, hence, the equilibrium adjustment to exogenous shocks.

We find that with no consumption channel, an exogenous 1% increase in housing demand increases mortgage borrowing by around 0.6%, but with $\omega = 0.82$ the increase in borrowing is 1.16%. This suggests that the total impact of the consumption channel on mortgage borrowing is very significant. All other elasticities in Fig 6 also increase in ω.

Figure 6: Transmission of shocks through the consumption channel



Values on vertical axis corresponds to the derivatives in Eq. (A16) in Appendix Section A.7.1. They can be interpreted as the elasticity of an endogenous outcome (mortgage borrowing or house price) with respect to an exogenous fundamental (a housing demand or credit supply shifter).

5.4 Counterfactuals

To quantify the role the consumption channel has played in shaping observed trends in loan sizes of buyers and house prices, we now use the model to solve for counterfactual trends in endogenous variables that would have resulted in the absence of the consumption channel.

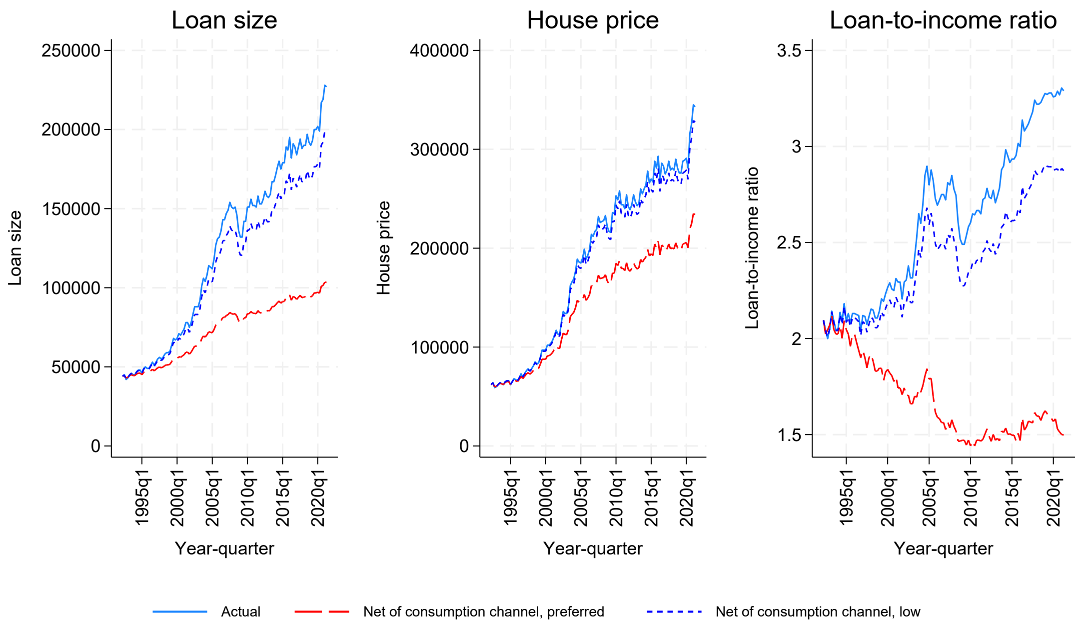
Theoretically, observed changes in the average mortgage borrowing of buyers, house prices, and any other endogenous variable in our model can be rationalized by a combination of exogenous shocks to any of the structural fundamentals in $\mathbf{V}$. In Appendix Section A.7.3, we parameterize multiple shocks to fundamentals as functions of observable variables to explore which fundamental shocks are key to rationalizing observed trends within our model. It turns out that income is our most powerful predictor. Indeed, we show in Appendix Section A.7.2 that our model already generates trends in endogenous outcomes that approximately match observed trends when we use changes in income as the sole source of exogenous shocks. Therefore, we use Eq. (21) to derive the counterfactual assuming that responses in endogenous variables are driven by exogenous changes in housing demand, exclusively. This approach has the advantage that we do not have to take any stance on the nature of housing demand shocks since we can express the counterfactual in the absence of the consumption channel solely as a function of model exogenous parameters and observed changes in endogenous outcomes. When we use both housing demand and credit supply shocks, our model can match actual trends in house prices and lending a little better, but the impact of the consumption channel is almost identical (see Section A.7.3).

Our simulations in the left panel of Figure 7 suggest that the consumption channel accounts for the majority of observed growth in mortgage borrowing and a sizable fraction of house prices of an average buyer in the UK since the early 1990s. Based on the ω estimate from the all-buyer-type sample, mortgage borrowing growth over the past 30 years would have been about 54% lower in the absence of the consumption channel. Even using the low estimate of $\omega = 0.1$, mortgage borrowing would have fallen by 12%.

The middle panel of Figure 7 illustrates how the consumption channel not only implies that the amount of borrowing increases in response to higher house prices; the additional liquidity also adds to housing demand, which translates into higher house prices. Based on the ω estimates from the all-buyer-type sample, we find that house prices would have appreciated about 32% less over the last 30 years if there was no consumption channel (4.6% with $\omega = 0.1$).

We conclude that the consumption channel is an important multiplier of the impact of exogenous shocks on outcomes on credit and housing markets. Indeed, we find that without it, house prices and average mortgage loan sizes would have increased by significantly less over the last three decades. Importantly, we also show that it is an important contributing factor to the empirically observed increase in LTIs because the multiplier effect on the loan size is greater than on the house price. In fact, our simulations in the right panel of Figure 7 suggest that without the consumption channel, LTIs would have fallen significantly over the past 30 years.

Figure 7: Counterfactual trends net of consumption channel



The solid lines present the actual trends observed in data. The dashed lines give counterfactual outcomes in the absence of a consumption channel, computed according to Eq. (21).

6 Conclusion

Our results offer a new perspective on the increase in household debt as a percentage of income that has been observed over several decades. House prices have been steeply rising and since households have not been able to or unwilling to substitute away from housing consumption (since housing and non-housing consumption are imperfect substitutes), they have increased borrowing. We call this mechanism the housing consumption channel in mortgage demand and show that this channel is quantitatively important in the UK, and accounts for a large proportion of the strong interaction between house prices and mortgage demand in the UK.

We provide several specific results that are of interest to lenders and policymakers. First, increasing house prices lead to greater debt burdens for buyers. This suggests that a high debt of buyers is a natural consequence of high house prices. Second, there is an important feedback loop between credit and housing markets as rising house prices increase mortgage demand while increasing credit supply can increase house prices. This suggests credit market shocks will have important indirect effects on both house prices and borrowing. Third, positive housing demand shocks translate into higher LTIs. This suggests that rising house prices can lead to a household debt crisis. This risk may generalize to other goods for which demand is inelastic and whose prices are exogenously determined (e.g. in international markets).

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A Online Appendix

This section contains material intended for online publication.

A.1 Derivatives of credit and housing demand

This section complements Section 3 in the main paper by highlighting the main mechanisms driving the consumption channel. The main ingredients we use are the elasticity of substitution between housing and non-housing as well as liquidity and deposit constraints. For clarity, we ignore the wealth channel and any temporal effects. These have already been discussed in the literature and incorporating them would complicate the model and obscure our main point. We begin with households who maximize their utility by choosing quantities of two goods: housing denoted by h and non-housing denoted by x. We assume a free choice between h and x so it is helpful to think of the households as buyers who face the problem of choosing their housing consumption. Preferences for consumption are given by a standard CES equation:

$$U(x,h) = \Big(\alpha x^{\varrho} + (1-\alpha)h^{\varrho}\Big)^{\frac{1}{\varrho}}, \tag{A1}$$

where, $0 < \alpha < 1$ and $-\infty < \varrho \leq 1$. In this setting, $\sigma = \frac{1}{1-\varrho}$ denotes an elasticity of substitution between housing and non-housing consumption. Housing and non-housing consumption become perfect substitutes as $\sigma \to \infty$ and perfect complements as $\sigma = 0$. The Cobb-Douglas special case is $\sigma = 1$ where changes in house prices do not affect expenditures on housing. For the intuitively plausible range of $0 < \sigma < 1$ (see Section 2), the expenditure share on housing increases with house prices. The optimal consumption of housing is therefore determined by the substitution elasticity σ.

The model has no time dimension expect for the following sequence of events. The buyer starts with savings (A) and information on income they will receive after they buy a house. To purchase a house the buyer can use their savings and a mortgage (L) but not income. Once a house is purchased, the buyer receives the income, purchases non-housing consumption and pays back the mortgage. I that can be interpreted as lifetime income if the buyer dies after paying back the mortgage (note we do not assume that people value bequests).

The buyer's decision is subject to two constraints. The first is a standard budget constraint: the cost of consumption cannot exceed the combined value of income and assets available at the time of making the decision. The second constraint is a liquidity constraint, which arises from the fact that the price of housing has to be paid before income is received. This means that buyers who do not have enough savings to buy a house with cash have to borrow in order to finance housing consumption. In our model, the liquidity constraint is the main reason for needing a mortgage and it is especially important for buyers with limited savings.

To define the household budget constraint, we denote the buyer (gross after taxes) housing price by g, the seller (net) price by n, and the price of the non-housing consumption basket by p. For simplicity, we assume that income is not subject to uncertainty. The two constraints are:

$$px + gh = I + A - rL \tag{A2}$$

$$L = \begin{cases} gh - A, \text{if } gh > A \\ 0, \text{if } gh \leq A, \end{cases}$$

where p is the price of x, g is the buyer price of h, I is income, A are assets, L is a mortgage loan and r is the cost of borrowing expressed as a percentage so that Lr gives the cost of the loan. The budget constraint equates the total cost of non-housing and housing consumption as well as the cost of borrowing to the present value or income and assets. The liquidity constraint simply states that the price of a house has to be lower or equal to the funds available at the time of making the choice (coming from either assets or a loan). The liquidity constraint also defines the demand for mortgage credit as a function of housing consumption, the buyer price of housing and assets. We focus on buyers who need loans ($gh > A$) which in the UK is around 80% of buyers.[15] Normalising the price of non-housing consumption to one and solving the model gives housing and mortgage demand expressions:

$$h = \frac{\mathrm{I} + A\,(r+1)}{g\,(r+1) + \left(\frac{ag\,(r+1)}{(1-a)}\right)^{\sigma}} \tag{A3}$$

$$L = \frac{g(\mathrm{I} + A\,(r+1))}{g\,(r+1) + \left(\frac{ag\,(r+1)}{(1-a)}\right)^{\sigma}} - A \tag{A4}$$

This yields a complex derivative for changes in housing demand when the buyer's price changes as well as for all key exogenous housing and credit market variables driving mortgage demand (g, n, r).

[15] For movers, the assets available at purchase can be considered as comprising of financial assets (savings) s and housing assets based on the value of the house one is moving out of $s_h = nh_s$. We think of them as constant or pre-determined for mover and zero for first time buyers. In both cases they are not correlated to changes in the buyer price and do not affect the consumption channel. Defining n as the seller price of housing that one is moving out of, gives assets as $A = s + nh_s$.

Changes in housing demand as a function of changes in buyer house price:

$$\frac{\partial h}{\partial g} = -\frac{(\mathrm{I} + A\,(r+1))\left(r + \frac{a^{\sigma}\,\sigma\,(g\,(r+1))^{\sigma-1}\,(r+1)}{(1-a)^{\sigma}} + 1\right)}{\left(g\,(r+1) + \frac{a^{\sigma}\,(g\,(r+1))^{\sigma}}{(1-a)^{\sigma}}\right)^{2}} \tag{A5}$$

Changes in housing demand as a function of changes in key exogenous housing and credit market variables driving mortgage demand (g, n, r).

$$\frac{\partial L}{\partial g} = \frac{I+A\,(r+1)}{(r+1)+\frac{a^{\sigma}\,(g\,(r+1))^{\sigma}}{(1-a)^{\sigma}}} - \frac{g\,(I+A\,(r+1))\left(r+\frac{a^{\sigma}\,\sigma\,(g\,(r+1))^{\sigma-1}\,(r+1)}{(1-a)^{\sigma}}+1\right)}{\left(g\,(r+1)+\frac{a^{\sigma}\,(g\,(r+1))^{\sigma}}{(1-a)^{\sigma}}\right)^{2}} \tag{A6}$$

$$\frac{\partial L}{\partial r} = \frac{A\,g}{g\,(r+1)+\frac{a^{\sigma}\,(g\,(r+1))^{\sigma}}{(1-a)^{\sigma}}} - \frac{g\,(\mathrm{I}+A\,(r+1))\left(g+\frac{a^{\sigma}\,g\,\sigma\,(g\,(r+1))^{\sigma-1}}{(1-a)^{\sigma}}\right)}{\left(g\,(r+1)+\frac{a^{\sigma}\,(g\,(r+1))^{\sigma}}{(1-a)^{\sigma}}\right)^{2}} \tag{A7}$$

Our central theoretical argument is that a low elasticity of substitution lends itself to a positive buyer price elasticity of mortgage demand. To formally illustrate this point, we derive an expression for $\frac{\partial L}{\partial g}$.

Although the expression is complex and gives little obvious insight into the impact of σ on the elasticity of mortgage demand to buyer prices, from Eq. (A4) it is clear that changes in g translate into changes of the denominator of the mortgage demand. Clearly, the impact these changes have on mortgage demand depends on the value of σ. We illustrate this in Figure 4 by graphing $\frac{\partial L}{\partial g}$ as a function of σ for selected values for all other parameters.[16]

The figure shows that the elasticity of mortgage demand to buyer prices increases when σ decreases. The sign of the presented function changes at 1. At this point, it is the Cobb-Douglas case where expenditure shares are always equal so mortgage demand does not change with price.

Intuitively, a buyer household with a given equity and income, *ceteris paribus*, will borrow more if house prices rise unless they reduce housing consumption at least proportionately to an increase in prices. In keeping with intuition, the elasticity decreases in σ since households find it easier to mitigate the effect of rising house prices on the budget by reducing housing consumption. Moreover, the elasticity decreases in the housing expenditure share and increases in the equity share. The positive buyer price elasticity of mortgage demand governs the consumption channel.

[16]Note that these values are for illustration only and have no interpretation. While they determine the shape of the line in the figure, they do not alter its key feature; mortgage elasticity of buyer prices is positive for $\sigma < 1$ and negative for $\sigma > 1$.

A.2 The static elasticity of substitution

This section complements Section 2 in the main paper by demonstrating how the static elasticity of substitution can be derived from a log-linear relationship between relative expenditures on housing and non-housing on the one hand and the price of housing on the other.

Adopting the same notations as in Section A.1, the static elasticity of substitution is defined as:

$$\sigma = \frac{d \ln \left(\frac{h}{x}\right)}{d \ln \left(\frac{\frac{\partial U}{\partial x}}{\frac{\partial U}{\partial h}}\right)} \tag{A8}$$

Using the first-order conditions of utility maximization and normalizing by the price of non-housing consumption ($p = 1$), we obtain:

$$\sigma = \frac{d \ln \left(\frac{h}{x}\right)}{d \ln \left(\frac{1}{g}\right)} \tag{A9}$$

Using the one-period budget constraint $I = x + gh$, where I denotes period income, we can express the consumption ratio as:

$$\frac{h}{x} = \frac{gh}{I - gh} \frac{1}{g} \tag{A10}$$

Using Eq. (A10) in Eq. (A9) and assuming a constant elasticity of substitution σ delivers:

$$\ln \frac{gh}{I - gh} = c + (1 - \sigma) \ln g \tag{A11}$$

Intuitively, the relative expenditure on housing increases in the price of housing if $\sigma < 1$. Eq. (A11) motivates a reduced-form estimation equation that can be taken to individual or area-level data. While housing expenditure gh (rent or annualized house prices) and income I are usually directly observable[17], the unit price of housing services g has to be estimated in auxiliary hedonic (Rosen, 1974) or repeat sales (Case and Shiller, 1989) regressions.

We present various estimates of that reduced-form relationship in Table A1. Columns (1-5) unambiguously point to static elasticity of substitution in the spatial cross-section of $\sigma < 1$. Notice that when we add spatial fixed effects in Column (6), housing consumption appears even less elastic. This is the expected mechanical result since we identify the relationship from changes over time in the short-run and

[17] We observe annual income. For house buyers, this approach can be reconciled with our model in the previous section if annual income is interpreted as a proxy for lifetime income.

housing supply is short-run inelastic, but it is not a sensible reflection of the true elasticity of substitution since sitting homeowners do not realistically (downward) adjust housing consumption in the short run.

Table A1: Static elasticity of substitution

	Ln consumption ratio ($\frac{gh}{I-gh}$)					
Ln house price index (g)	0.299***	0.182***	0.353***	0.360***	0.702***	1.237***
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)	(0.02)
σ	0.70	0.82	0.65	0.64	0.30	-0.24
Postcode sector effects	-	Yes	-	Yes	-	Yes
Year effects	-	Yes	-	Yes	-	Yes
N	11,950	10,486	12,008	12,008	13,931	13,316
r2	.259	.915	.303	.312	.661	.967

Notes: Unit of observation is postcode sector-year. Consumption ratio is the ratio of housing consumption housing (gh) over non-housing consumption ($I - gh$), where the latter is measured as the difference between gross household income I and housing cost gh. Micro-foundations for the inference of δ are provided in Appendix Section A.2. House price index (g) is a mix-adjusted hedonic index based on the UK land registry data which covers the universe of transactions. Income data are from the Office for national Statistics and rent data are from Zoopla provided by the Urban Big Data Centre. Annualized house price is the mean house price as recorded in the land registry data, annualized for an infinite horizon at a discount rate of 5%. Standard errors in parentheses. $^{+}$ $p < 0.15$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

A.3 Data

This section complements Section 4.4 in the main paper by adding additional detail on the data collection and processing.

A.3.1 Notes on dataset construction

As discussed in Section 4.4, we combine information from the universe of property transactions (Land Registry) with the universe of mortgage originations, and specifically focus on properties transacted with an underlying mortgage.

Table A2 provides a reconciliation from the Land Registry dataset to our sample of roughly 700,000 observations used for estimation in this paper. As indicated in the first row of Table A2, our starting point is the 14.82 Mn housing transactions in the UK from 2005-2017. 14.12 Mn of these have a unique combination of property postcode, transacted price and date (year-quarter). These variables are also present in the mortgage originations data, and we are able to track 37% of the Land Registry observations in the latter. Thus, our analysis suggests that roughly 2/3rd of property transactions in the UK are cash-based or bought by landlords for renting.

In the remaining 5.28 Mn mortgage-based housing transactions, we observe both mortgage (interest rate and issuing lender) and borrower (income and age) characteristics. Of these, we specifically focus on properties that are transacted more than once between 2005-2017, leaving us with 701,383 observations. In this repeat-sale sample, 139,810 observations pertain to properties that are transacted more than once specifically by first-time-buyers, and 244,138 to repeat-sales by home-movers. The summary statistics for these sub-samples are shown in Tables A3 and A4, respectively. The transactions with first-time-buyers involve lower house prices and mortgage sizes, higher leverage, and younger borrowers with lower incomes.

Table A2: Steps in Dataset Construction

	Drop (#, Mn)	Total (#, Mn)
Number of transactions (2005-2017)		14.82
Drop if non-unique postcode, transacted price & date	0.70	14.12
Drop if cash transactions	8.84	5.28
Drop if non-repeat transactions	4.58	0.70
Sample for estimating housing consumption channel		0.70

The table shows the total number of observations in the land registry dataset (row 1), and the number of observations dropped (column 2) and the number of observations left (column 3) after each data filtering step. This reconciles to our overall sample of 701,383 observations used to estimate the parameter governing the housing consumption channel of mortgage demand.

A.3.2 Property price indices

We create property prices indices at a MSOA level based on the average price of all housing transactions in a given MSOA in a given quarter. We use these indices to reflect house prices for each transaction to levels in 1991 and 2013. Transaction-level data is only available since 1995 so in order to predict prices in 1991 we use regional house price indices from Nationwide Building Society between 1991 and 1995. The predicted 1991 price is used to estimate the council-tax band for each property (i.e., the instrument for seller price, see Section 4.3.2). We also use binned-deciles of the estimated house prices (in 1991 and 2013) interacted with quarterly dummies to create controls for price trends when estimating ω, the principle parameter governing the housing consumption channel through GMM. See Section 4.2 for a discussion, where we discuss how price trends described here act as controls for deterministic components of mortgage quantities and price in our estimation approach.

Table A3: Summary Statistics for first-time-buyer transactions (2005-2017)

	mean	sd	p10	p50	p90
Price	185,061	94,660	99,950	160,000	300,000
Predicted price (2013)	172,675	89,449	90,899	150,974	276,978
Predicted price (1991)	51,547	17,978	32,284	48,644	73,761
Stamp duty	1148.322	2662.321	0.000	0.000	2230.000
log(Loan value)	11.824	0.444	11.296	11.802	12.390
log(Int. rate)	-3.256	0.412	-3.821	-3.161	-2.815
log(Price)	12.027	0.436	11.512	11.983	12.612
log(1+Tax rate)	0.005	0.008	0.000	0.000	0.010
Tax instrument	0.006	0.009	0.000	0.000	0.030
Price instrument	0.012	0.010	0.003	0.006	0.026
Loan value	150,878	73,547	80,499	133,500	240,503
LTI	3.52	1.18	2.40	3.53	4.57
Income	44,919	24,883	23,318	39,643	70,328
Age	29	6	23	28	37
Observations	139,810				

The table shows summary statistics for land registry transactions that are associated with an underlying property that is transacted at least twice between 2005-2017 through a mortgage by fist-time-buyers. This sample is used for estimating the parameter governing the housing consumption channel.

Table A4: Summary Statistics for home-mover transactions (2005-2017)

	mean	sd	p10	p50	p90
Price	302,438	187,591	148,500	249,950	500,000
Predicted price (2013)	291,272	185,736	139,716	241,038	492,990
Predicted price (1991)	90,497	47,317	47,893	78,889	145,826
Stamp duty	4622.826	7624.543	0.000	1865.000	1.2e+04
log(Loan value)	11.994	0.623	11.225	12.028	12.737
log(Int. rate)	-3.381	0.484	-4.034	-3.273	-2.859
log(Price)	12.484	0.496	11.908	12.429	13.122
log(1+Tax rate)	0.012	0.013	0.000	0.010	0.030
Tax instrument	0.014	0.014	0.000	0.010	0.030
Price instrument	0.008	0.007	0.002	0.004	0.019
Loan value	193,472	120,059	75,000	167,295	340,000
LTI	3.15	1.53	1.70	3.18	4.44
Income	65,553	44,461	28,500	54,605	111,580
Age	39	9	28	37	52
Observations	244,138				

The table shows summary statistics for land registry transactions that are associated with an underlying property that is transacted at least twice between 2005-2017 through a mortgage by home-movers. This sample is used for estimating the parameter governing the housing consumption channel.

A.4 Interest rate elasticity of mortgage supply

To estimate the price elasticity of mortgage supply, ρ, we take advantage of the fact that in the UK, the mortgage market is based on "menu" prices rather than on individual negations (Benetton, 2021). This means that lenders decide what prices they are willing to offer at certain LTVs and any borrower who meets their affordability standards will be offered the same price that differs only with their LTV. In practice, this means that the mortgage rates we observe in our data reflect the supply at different quantities adjusted for collateral value (LTVs). We can use this fact to estimate the following (rearranged) version of Eq. (2) on our data:

$$\ln \frac{L}{n^{\zeta}} = \rho \ln r + \ln \mathcal{S} \tag{A12}$$

Since we know loan sizes, asset prices, and mortgage rates, we can estimate the value of ρ directly. Notice that under our baseline parameterization with $\zeta = 1$, we obtain the log loan-to-value ratio on the left-hand side of the equation. While we think this is a reasonable assumption, it is also possible to move the seller price to the right-hand side of the equation and use $\ln L$ as the outcome variable. While there are important issues with this specification as loan sizes and prices are choices that households make (unlike the exogenous interest rate that is determined purely by the supply curve), this specification does not require assuming a value of ζ. It turns out that this makes very little difference for estimates of ρ, which further supports our parameter choices. Results are presented in Table A5 and motivate our choice of $\rho = 0.3$.

A.5 Excluded instruments

This section complements Sections 4.3.1 and 4.3.2 in the main paper by providing additional detail on the seller price instrument and documenting the relevance of both instruments.

A.5.1 Council tax instrument

This section complements Section 4.3.2 in the main paper by providing further background on the seller price instrument introduced in Eq. (18).

Assuming that council taxes depreciate the asset value $n_j h_j$ by the present value of council taxes, we can express $n_j h_j$ as:

$$n_j h_j = n_j^N h_j^N - \delta^T CT_j,$$

Table A5: Mortgage rate elasticity of credit supply

Sample	All					
	(1)	(2)	(3)	(4)	(5)	(6)
log(r)	0.110***	0.286***	0.294***	0.276***	0.294***	0.337***
	(0.0011)	(0.0015)	(0.0015)	(0.0015)	(0.0016)	(0.0033)
log(n)	0.840***	0.823***	0.858***	0.783***	0.799***	0.809***
	(0.0009)	(0.0029)	(0.0009)	(0.0014)	(0.0041)	(0.0081)
Observations	701,383	701,383	701,383	701,383	701,383	262,970
R^2	0.551	0.573	0.589	0.63	0.645	0.747
Price tr.		Yes			Yes	
Lender tr.			Yes		Yes	
Area tr.				Yes	Yes	
Com. FE						Yes

Table shows estimates of ρ based on the regression specification described in Section A.4, and estimated in the sample of repeat sale properties used for Table 3. 'Area tr.' are MSOA fixed effects interacted with quarterly time trends; 'Price tr.' are price bands (deciles, based on transacted prices projected to 2013) interacted with quarterly time trends; and 'Lender tr.' are lender dummies interacted with yearly time trends. 'Com. FE' is a combination of all the above fixed effects interacted with each other (i.e. price×lender×area×quarters). Standard errors in parentheses (* p < 0.1, ** p < 0.05, *** p < 0.01).

where $n_j^N h_j^N$ is the counterfactual asset value in the absence of the council tax and δ^T is an arbitrary discount factor. Using that the council tax rate can be expressed as

$$CTR_j = \frac{\delta^T CT_j}{n_j h_j},$$

it is straightforward to solve for

$$\ln n_j = \ln n_j^N + \ln h_j^N - \ln h_j^N - \ln(1 + CTR_j)$$

By using $\ln(1+\widehat{CTR_j})$ as an instrument for n_j, we remove the potentially endogenous variation in $\{n_j^N, h_j, h_j^N\}$. We also remove the potentially endogenous variation in $\ln(1 + CTR_j)$ that arises from $\{n_j^N, h_j\}$ being components of CTR_j.

In keeping with intuition, the council tax rate should depreciate the seller price. To further develop the intuition, we present some numerical illustrations in Table A6.

A.5.2 Instrument relevance

Below, we present ancillary regressions based on instruments discussed in Section 4 that support the relevance of our instruments. They are equivalent to first-stage regressions in a 2SLS approach and meant to show that even after controlling for

Table A6: Changes in Council Tax amounts and capitalization in house prices

ID	Value in 1993	Band	Value in 2000	CT in 2000	10% increase	PV of increase (at 5%)
1	£65,000	C	£250,000	£890 (0.36%)	£89	£1,780 (0.7%)
2	£90,000	E	£250,000	£1,220 (0.49%)	£122	£2,440 (1%)
3	£53,000	C	£200,000	£890 (0.45%)	£89	£1,780 (0.9%)

Table presents a hypothetical example of how a 10% increase in Council Tax in 2000 is capitalised into property prices of different properties. The effect on prices is given in the last column and assumes a 5% discount rate. The table shows that even prices of properties that have the same starting price but are in different tax bands will react differently to a percentage increase in Council Tax. The same will be true for properties in the same band but with different starting prices. CT stands for Council Tax. The assumed increase in the tax amount is 10% (given in column 6). Year 2000 is selected for illustration purposes only and has no meaning other than denoting a specific time period. An average tax increase in our sample was around 5% per year. In 2018 the average house price was around £220,000 and the average Council Tax for band D around £1,671 - reported by the Ministry of Housing, Communities and Local Government.

multiple fixed effects and borrower characteristics, our instruments are still relevant.

Transaction taxes instrument (reform of the tax schedule):

$$\begin{aligned}\ln(1+\widetilde{\tau})_{i,j,k,t} =& \beta^h \ln(1+H_t(\bar{n}_{j,t=2013})) + \beta^{CT} \ln(1+CT_r)_{j,k,t} + \\ & \mathbf{X_i'b} + \mu_j + \eta_{k,t} + n_{j,t=2013} + \epsilon_{i,j,k,t},\end{aligned} \tag{A13}$$

where $H_t(n_{i,t=2013})$ is the change in transaction tax rate due to the 2014 reform estimated based on the 2013 price (zero for all periods before the reform), $\ln(1+CT_r)$ denotes the seller price instrument, β denotes coefficients of the two instruments, $\mathbf{X_i}$ is a column vector of buyer characteristics and $\mathbf{b}$ is a column vector of corresponding parameters, μ_j denotes property fixed effects, $\eta_{k,t}$ area fixed effects interacted with a time trend and $n_{j,t=2013}$ denotes a 2013 estimated price band fixed effect interaction with a time trend (note that parameters are suppressed for all fixed effects).

Seller price instrument (changes in property tax) :

$$\begin{aligned}\bar{n}_{i,j,K,t} =& \beta^h \ln(1+H_t(\bar{n}_{j,t=2013})) + \beta^{CT} \ln(1+CT_r)_{j,k,t} + \\ & \mathbf{X_i'b} + \mu_j + \eta_{k,t} + n_{j,t=2013} + \epsilon_{i,j,k,t},\end{aligned} \tag{A14}$$

where all independent variables are the same as in Eq. A13 (note that β parameters have the same subscripts but are expected to take different values) except the outcome variable is the seller price.

The results in Table A7 show that the regressions explain over 95% of variation in the dependent variable in all cases. This is not surprising as our fixed effects and control variables capture many factors. More importantly, Columns 1 to 3 show that revisions in the tax schedule indeed, are a significant driver of transaction taxes. This is consistent across all estimation samples although seems to be more important for movers than it is for FTBs. This is likely because there are more FTBs in the lowest part of the price distribution (0-125k) where the transaction tax rate did not change but remained zero. It may seem surprising that Council Tax rates are correlated with transaction tax rates but the results have to be interpreted in the context of the magnitudes of the variables. Since CT_r takes very small values (usually less than 0.5% of property price) and changes by very little (usually increases are no more than 4% per year), the magnitudes of the coefficients can be interpreted as economically insignificant. Columns 4 to 6 show the impact of the two instruments on prices. All results are exactly as expected; a 1% in the transaction tax rate translates into a much larger increase in prices as described by Best and Kleven (2017) and increases in property taxes reduce prices as described by Koster and Pinchbeck (2022).

Table A7: Instrumented variables regressed on instruments and controls

	log(1+τ)			log(price)		
	All (1)	FTB (2)	HM (3)	All (4)	FTB (5)	HM (6)
ln(1+H$_t$($\bar{n}_{t=2013}$))	0.371***	0.253***	0.394***	2.964***	2.899***	3.231***
	(0.0016)	(0.0043)	(0.0032)	(0.0250)	(0.0711)	(0.0471)
ln(1+CT$_r$)	-0.104***	-0.123***	-0.126***	-20.635***	-19.590***	-27.277***
	(0.0072)	(0.0144)	(0.0211)	(0.1103)	(0.2408)	(0.3104)
Observations	701,383	139,810	244,138	701,383	139,810	244,138
R2	0.96	0.96	0.97	1.00	1.00	1.00
Adj. R2	0.91	0.86	0.92	0.99	0.99	0.99
Prop. FE	Yes	Yes	Yes	Yes	Yes	Yes
Area tr.	Yes	Yes	Yes	Yes	Yes	Yes
Price '91 tr.	Yes	Yes	Yes	Yes	Yes	Yes
Price '13 tr.	Yes	Yes	Yes	Yes	Yes	Yes
Buyer char.	Yes	Yes	Yes	Yes	Yes	Yes
Lender tr.	Yes	Yes	Yes	Yes	Yes	Yes

Table shows instrument relevance by regressing the transaction tax (log$(1+\tau)$) and transaction price (log(price)) on the two instruments: $H_t(n_{i,t=2013})$ is the change in transaction tax rate due to the 2014 reform estimated based on the projected price in 2013 (zero for all transactions before the reform); $ln(1+CT_r)$ denotes the seller price instrument. 'Prop. FE' are property fixed effects; 'Area tr.' are MSOA fixed effects interacted with quarterly time trends; 'Buyer char.' refers to controls for borrower income, age and whether first time buyer or previous owners; 'Price '91 tr' are price bands (deciles, based on transacted prices projected to 1991) interacted with quarterly time trends; 'Price '13 tr'. are price bands (deciles, based on transacted prices projected to 2013) interacted with quarterly time trends; and 'Lender tr.' are lender dummies interacted with yearly time trends. Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$).

A.6 Robustness

This section complements Section 4.5 in the main paper by additional detail on various robustness tests.

A.6.1 Robustness results with different controls

In Table 3, we show our main result with different controls and demonstrate that our conclusions hold in a more parsimonious model that includes just property fixed effects and area trends as controls. This makes it arguably less likely that there is an important unobserved factor that we fail to control for.

Table A8: Structural estimation results with different controls

	(1)	(2)	(3)	(4)	(5)	(6)
ω	1.093***	0.753***	0.752***	0.801***	0.806***	0.818***
	(0.00405)	(0.00886)	(0.0222)	(0.0220)	(0.0206)	(0.0120)
Observations	701,383	701,383	701,383	701,383	701,383	701,383
Price '91 tr.		Yes	Yes	Yes	Yes	Yes
Price '13 tr.		Yes	Yes	Yes	Yes	Yes
Prop. FE			Yes	Yes	Yes	Yes
Buyer char.				Yes	Yes	Yes
Area tr.					Yes	Yes
Lender tr.						Yes

Table shows the robustness of the coefficient reported in column 3 of Table 3 to the sequential inclusion of controls, and are based on including both moment conditions and instruments. 'Prop. FE' are property fixed effects; 'Area tr.' are MSOA fixed effects interacted with quarterly time trends; 'Buyer char.' refers to controls for borrower income, age and whether first time buyer or previous owners; 'Price '91 tr' are price bands (deciles, based on transacted prices projected to 1991) interacted with quarterly time trends; 'Price '13 tr'. are price bands (deciles, based on transacted prices projected to 2013) interacted with quarterly time trends; and 'Lender tr.' are lender dummies interacted with yearly time trends. Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$).

A.6.2 Estimates with single equations

Table 3 shows estimates of ω using both the mortgage quantities and mortgage price moment conditions. In Table A9, we implement GMM using either of the two moment conditions: the mortgage loan equation in panel (a), and the mortgage price equation in panel (b). Results based on mortgage quantities are quantitatively and qualitatively (i.e. across the sub-samples with all borrower types, and only first-time-buyers or movers) similar with those reported in Table 3. However, estimates relying only on the mortgage price equation give results that are less precisely estimated. They offer weaker evidence in support of the consumption channel and some coefficients are not statistically significant. There is no obvious reason for this but it is worth noting that the mortgage prices in our data are "menu" prices and tend to take time to adjust to market changes. This may introduce a source of bias in our data. For example, the mortgage offer issued by the lender is usually valid for up to six months from the issue date. It specifics terms of the loan (inc. the interest rate) and the maximum lending amount on these terms.

Table A9: Structural estimation results of omega using single moment conditions

(a) Only mortgage quantity equation

	All			FTB			HM		
	i	ii	iii	i	ii	iii	i	ii	iii
ω	0.880***	0.758***	0.842***	0.876***	0.838***	0.867***	0.926***	0.862***	0.899***
	(0.0143)	(0.0207)	(0.0121)	(0.0303)	(0.0505)	(0.0270)	(0.0317)	(0.0370)	(0.0248)
Observations	701,383	701,383	701,383	139,810	139,810	139,810	244,138	244,138	244,138
CT IV	Yes		Yes	Yes		Yes	Yes		Yes
SDLT IV		Yes	Yes		Yes	Yes		Yes	Yes
Loan eq.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interest eq.									
Controls	Same as Table 3								

(b) Only mortgage interest rate equation

	All			FTB			HM		
	i	ii	iii	i	ii	iii	i	ii	iii
ω	0.109**	0.0531	0.0932**	0.240***	0.234	0.239***	-0.124	-0.205	-0.158
	(0.0491)	(0.0766)	(0.0426)	(0.0798)	(0.147)	(0.0727)	(0.123)	(0.143)	(0.0962)
Observations	701,383	701,383	701,383	139,810	139,810	139,810	244,138	244,138	244,138
CT IV	Yes		Yes	Yes		Yes	Yes		Yes
SDLT IV		Yes	Yes		Yes	Yes		Yes	Yes
Loan eq.									
Interst eq.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Same as Table 3								

Table shares GMM estimates of ω using different sub-samples, and combinations of moment conditions and instruments as shown in the column headings. ‘All’ refers to a sample of repeat sale properties including all buyers, ‘FTB’ refers to a sample of repeat sale properties bought by first time buyers, and ‘Movers’ refers to a sample of repeat sale properties bought by previous owners. ‘CT IV’ is the council-tax instrument for seller prices. ‘SDLT IV’ is the Stamp Duty Land Tax reform instrument for transaction tax rates. ‘Loan eq.’ refers to moment conditions from the mortgage quantity equation outlined in Eq. (15) and ‘Interest eq.’ to conditions from Eq. (16). Panel (a) solely uses the moment condition from the mortgage quantity equation; panel (b) solely uses the moment condition from mortgage price equation. Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$).

A.6.3 Additional sub-sample results

We estimate our baseline (and preferred) approach of estimating ω (using both moment conditions and both instruments) in sub-samples by property type (whether detached, semi-detached or terraced; or whether freehold or leasehold) and borrower-type (borrower age or income).

Panel (a) of Table A10 shows that the estimated ω is stronger for terraced properties as opposed to detached and semi-detached properties. This suggests that the housing consumption channel is particularly strong for borrowers at the bottom of the housing ladder; terraced houses include flats are more likely to be the first property owned by households, detached properties being a lot larger and more expensive in comparison.

Similarly, the estimated ω is stronger for borrowers with lower incomes (panel (c)), but the estimated ω among younger and older borrowers are quite close. The estimated ω by tenure type (i.e. whether a freehold or leasehold) of the property is also similar.

A.6.4 Grid search results

To ensure that our estimates identify a global minimum in the objective function, we performed a grid search over different parameters of ω. For each value, we evaluate the goodness of fit of our model by computing the root mean square error. Figure A1 reveals that the objective function is well-behaved in a large parameter space. The objective function is minimized exactly at the value estimated by our GMM procedure, confirming that the GMM estimates recover the value that best fits globally.

A.6.5 Monte Carlo simulations

To account for the uncertainty surrounding the set values of parameters $\{\theta, \zeta, \rho\}$ in our GMM estimation, we also performed Monte Carlo simulations to recover more conservative confidence intervals. Following the standard approach to bootstrapping standard errors, we draw random samples with replacements in each Monte Carlo experiment. It is well-known that the sampling distribution of our relative statistic (ω) across bootstrap samples represents a good approximation of the standard error. To incorporate uncertainty in the values of the set parameters $\{\theta, \zeta, \rho\}$, we draw their

Table A10: Structural estimation results of omega in alternate sub-samples

(a) By property type

	Detached	Semi-detached	Terraced
ω	0.673***	0.819***	0.858***
	(0.0451)	(0.0254)	(0.0238)
Observations	101,887	184,732	204,720
CT IV	Yes	Yes	Yes
SDLT IV	Yes	Yes	Yes
Loan eq.	Yes	Yes	Yes
Interest eq.	Yes	Yes	Yes
Controls		Same as Table 3	

(b) By tenure type

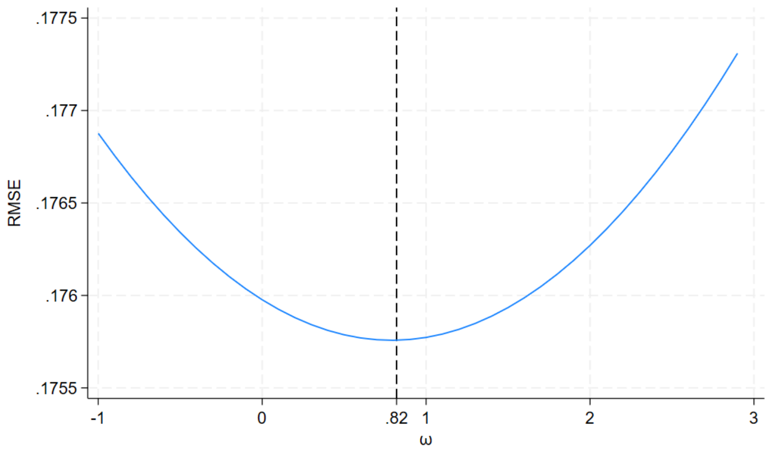
	Leasehold	Freehold
ω	0.813***	0.809***
	(0.0144)	(0.0252)
Observations	552,079	114,004
Moments/Instruments/Controls	Same as panel (a)	

(c) By age and income

	Income		Age	
	I	II	I	II
ω	0.864***	0.816***	0.814***	0.811***
	(0.0232)	(0.0233)	(0.0265)	(0.0302)
Observations	207,663	222,266	166,384	180,664
Moments/Instruments/Controls		Same as panel (a)		

Table shares GMM estimates of ω using different sub-samples, and combinations of moment conditions and instruments as shown in the column headings. Estimates in panel (a) are based on repeat sale properties that are detached, semi-detached or terraced; panel (b) are based on repeat sale properties that are leasehold or freehold; and panel (c) are based on borrower age and income, where (I) refers to borrowers below the median and (II) to borrowers above the median. 'CT IV' is the council-tax instrument for seller prices. 'SDLT IV' is the Stamp Duty Land Tax reform instrument for transaction tax rates. 'Loan eq.' refers to moment conditions from the mortgage quantity equation outlined in Eq. (15) and 'Interest eq.' to conditions from Eq. (16). 'Prop. FE' are property fixed effects; 'Area tr.' are MSOA fixed effects interacted with quarterly time trends; 'Buyer char.' refers to controls for borrower income, age and whether first time buyer or previous owners; 'Price '91 tr' are price bands (deciles, based on transacted prices projected to 1991) interacted with quarterly time trends; 'Price '13 tr'. are price bands (deciles, based on transacted prices projected to 2013) interacted with quarterly time trends; and 'Lender tr.' are lender dummies interacted with yearly time trends. Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$).

Figure A1: Grid search over values of Omega



The vertical axis gives the Root mean squared error values of our system of equations with zeta set to 1, rho set to 11 and theta set to -0.5. The horizontal axis gives different values of omega.

values from the following distributions in each Monte Carlo experiment.

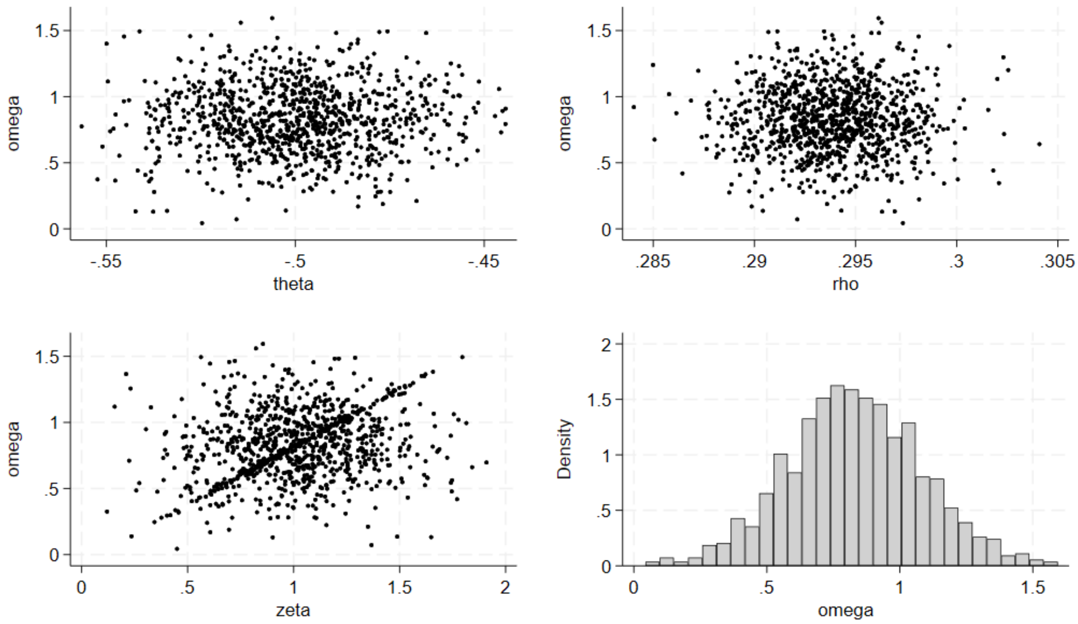
$$\theta \sim \mathcal{N}(-0.5,\, (0.2)^2)$$
$$\zeta \sim \mathcal{N}(1,\, 0.3^2)$$
$$\rho \sim \mathcal{N}(\hat{\rho}(\zeta), (\hat{\sigma}_{\rho(\zeta)})^2)$$

For θ, the second moment is the standard error from Best et al. (2019). For θ, the degree of uncertainty is more difficult to assess. We choose, admittedly somewhat arbitrarily, to draw the parameter value from a distribution with a coefficient of variation of 0.3 to allow for a sizable degree of variation. To be fully theory-consistent, we need to take into account that the value of ρ is not independent of ζ. Therefore, in each Monte Carlo simulation, we first estimate ρ, conditional on the drawn ζ value, using the procedure described in Section A.4. Then we use the point estimate and the standard error from this estimation to define the first and second moment of the distribution from which we draw our value of ρ. Hence, the moments of our distribution are estimated conditional on ζ as $\hat{\rho}(\zeta)$ and $\hat{\sigma}_{\rho(\zeta)}$.

We summarize some results of the Monte Carlo procedure in Figure A2. The most notable result is the sampling distribution presented in the bottom-right panel. As expected, we find that the distribution has a mean value of 0.82, exactly the GMM estimate. More importantly, the standard deviation of this distribution is 0.25. This corresponds to a much larger standard error than returned by the naive GMM estimation that abstracts from uncertainty in set parameter values in Table 3. Still, we can comfortably reject $\omega = 0$ at the 1% confidence level.

An ancillary finding of the Monte Carlo simulation exercise is that our ω estimates are fairly insensitive to the choice of θ and ρ. The choice of ζ is more consequential. However, for ω to approach zero, we have to choose ζ values that are close to zero, which is theoretically implausible. It would imply that banks in the UK relate the interest rate charged to the loan size and not the loan-to-value ratio, which is not how the market works.

Figure A2: Monte Carlo simulation results



The figure presents Monte Carlo simulation results over 1000 estimations of Eq (A25) with different values of parameters rho, zeta and omega.

A.7 Counterfactuals

A.7.1 Mapping changes in fundamentals to changes in outcomes

This section complements Section 5.1 in the main paper by laying out the mapping from $\hat{\mathbf{V}}$ into $\hat{\mathbf{W}}$. To this end, it is useful to express the relative change in endogenous outcomes as:

$$\hat{\mathbf{W}} = \exp\left(\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}} \ln \hat{\mathbf{V}}\right), \tag{A15}$$

where we have used $\ln \hat{\mathbf{V}} \equiv \ln \mathbf{V^C} - \ln \mathbf{V^0}$. To derive $\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}$, we log-linearize the housing demand and supply Eqs. (19) and (20) and use the buyer price definition

$g = (1+\tau)n$ to obtain

$$\ln h_D = \tilde{\mathcal{D}}_H + \xi \ln \bar{n} + \kappa \ln((1+\tau)n) + \lambda \ln L$$
$$\ln h_S = \tilde{\mathcal{S}}_H + \eta \ln n,$$

Using log-linearized versions of Eqs (1) and (2) and the market clearing conditions

$$\ln h = h_D = h_S$$
$$\ln L = L_D = L_S,$$

we can express h and L solely as functions of the structural parameters and fundamentals, which allows us to derive the following derivatives of interest:

$$\begin{aligned}
\frac{\partial \ln L}{\partial \ln \tilde{\mathcal{S}}_L} &= \frac{-\theta(\eta-\kappa)}{(\rho-\theta)(\eta-\kappa)-\lambda(\rho\omega-\theta\zeta)} \\
\frac{\partial \ln n}{\partial \ln \tilde{\mathcal{S}}_L} &= \frac{-\lambda\theta}{(\rho-\theta)(\eta-\kappa)-\lambda(\rho\omega-\theta\zeta)} \\
\frac{\partial \ln L}{\partial \ln \tilde{\mathcal{D}}_H} &= \frac{\rho\omega-\theta\zeta}{(\rho-\theta)(\eta-\kappa)-\lambda(\rho\omega-\theta\zeta)} \\
\frac{\partial \ln n}{\partial \ln \tilde{\mathcal{D}}_H} &= \frac{\rho-\theta}{(\rho-\theta)(\eta-\kappa)-\lambda(\rho\omega-\theta\zeta)}
\end{aligned} \tag{A16}$$

A.7.2 One demand or supply shifter

Using Eqs. (A16) and (A15) it is straightforward to compute endogenous counterfactual outcomes for given initial values of endogenous outcomes and relative changes in exogenous fundamentals:

$$\mathbf{W^{CC}} = \exp\left(\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}} \ln \hat{\mathbf{V}}\right) \mathbf{W^0} \tag{A17}$$

Since all derivatives in Eq. (A16) depend on ω, it is immediate that the counterfactual outcomes $\mathbf{W^{CC}}$ will also depend on ω and, hence, the relative importance of the consumption channel in mortgage demand. Let's now consider an alternative counterfactual

$$\mathbf{W^{NCC}} = \exp\left(\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}} \ln \hat{\mathbf{V}}\right) \mathbf{W^0}, \tag{A18}$$

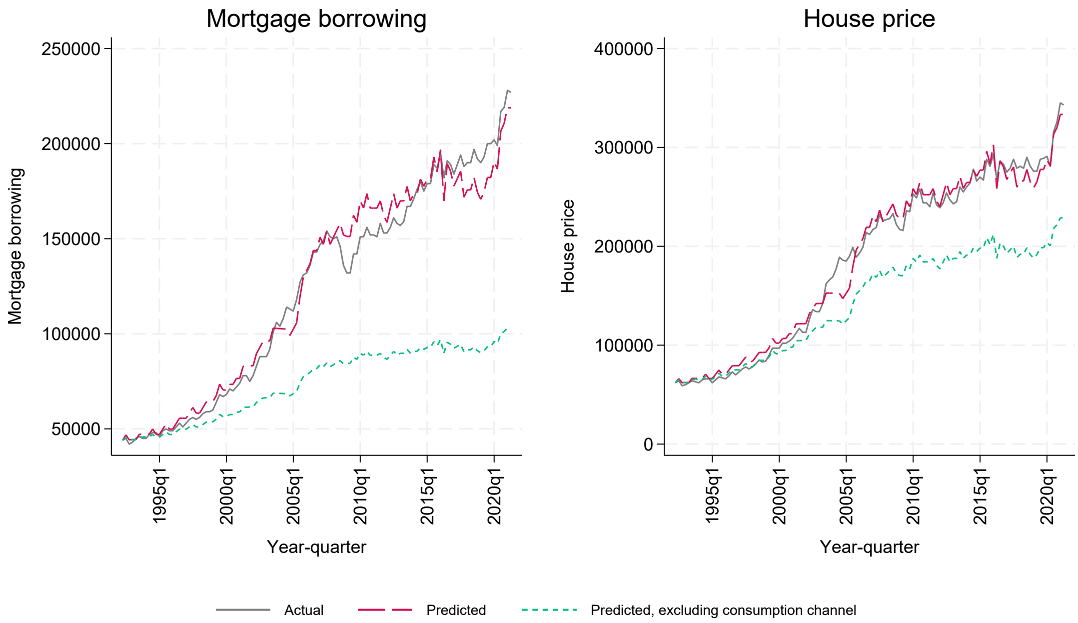
where $\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}}$ represents the derivative when $\omega = 0$. Using Eq. (A15), we can express this counterfactual as

$$\mathbf{W}^{\mathbf{NCC}} = \exp\left(\frac{\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln \mathbf{V}}}}{\frac{d \ln \mathbf{W}}{d \ln \mathbf{V}}} \ln \hat{\mathbf{W}}\right) \mathbf{W}^{\mathbf{0}}, \tag{A19}$$

where $\ln \hat{\mathbf{W}}$ is the log change in an outcome over an arbitrary period observed in data.

In Figure A3, we illustrate how our model predicts changes in mortgage borrowing and housing prices using Eq. (A20) and relative changes in income as the sole change in exogenous fundamentals ($\hat{\mathbf{V}}$). It turns out that under our parameterization, our model already generates trends in mortgage borrowing and house prices that closely match observed trends. Hence, we use the transparent case with one demand shifter as the baseline approach to establish the counterfactual in the absence of the consumption channel according to Eq (A22).

Figure A3: Actual vs. predicted trends I: Income as demand shifter



The solid lines present the actual trends observed in data. The dashed lines give predictions (in presence of a consumption channel), computed according to Eq. (A20). The long-dashed line uses the $\{\omega\}$ from the all-buyer-type sample in Table 3, Column 3. The short-dashed line uses the $\{\omega\}$ from the FTB sample in Table 3, Column 6.

A.7.3 Multiple demand and supply shifters

Of course, any outcome in $\mathbf{W}$ can be shifted by changes in any of the exogenous fundamentals in $\mathbf{V}$. Using Eqs. (A16) and (A15) it is straightforward to compute endogenous counterfactual outcomes for given initial values of endogenous outcomes and relative changes in exogenous fundamentals:

$$\mathbf{W^{CC}} = \prod_{m}^{M} \left[\exp\left(\frac{\partial \ln \mathbf{W}}{\partial \ln V^m} \ln \hat{V}^m \right) \right] \mathbf{W}^0, \tag{A20}$$

where V^m is one of M exogenous fundamentals in $\mathbf{V}$. Since changes in exogenous fundamentals cannot be observed directly, we parametrize them as

$$\ln \hat{V}^m = \beta^m \ln \hat{U}^m, \tag{A21}$$

where $\ln \hat{U}^m$ is an observable relative change in a factor of demand or supply of mortgages or housing and β^m is an elasticity parameter that monitors the effect size. We can express an alternative counterfactual that results from the same exogenous shocks in the absence of the consumption channel as:

$$\mathbf{W^{NCC}} = \prod_{m}^{M} \left[\exp\left(\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln V^m}} \ln \hat{V}^m \right) \right] \mathbf{W}^0, \tag{A22}$$

where each $\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln V^m}}$ is one of the derivatives in Eq. (A16) when $\omega = 0$. We denote the relative change from the counterfactual with and without the consumption channel by $\widehat{\mathbf{W}}^{\mathbf{NCC}} = \frac{\mathbf{W}^{NCC}}{\mathbf{W}^{CC}}$ and nest it into $\mathbf{W}^{CC} = \widehat{\mathbf{W}}\mathbf{W^0}$, to obtain:

$$\mathbf{W}^{NCC} = \widehat{\mathbf{W}}^{NCC} \widehat{\mathbf{W}} \mathbf{W^0}, \tag{A23}$$

which intuitively states that any endogenous counterfactual outcome in the absence of the consumption channel $\mathbf{W}^{NCC}$ can be expressed as a function of an observed initial value $\mathbf{W}^0$, an observed relative change over a given period $\widehat{\mathbf{W}}$, and the relative change that results from a different response to a fundamental shock with and without the consumption channel $\widehat{\mathbf{W}}^{NCC}$. Using Eqs. (A20), (A21), (A22) in Eq. (A23), we obtain:

$$\mathbf{W}^{NCC} = \frac{\prod_m^M \left[\exp\left(\widetilde{\frac{\partial \ln \mathbf{W}}{\partial \ln V^m}} \beta^m \ln \hat{U}^m \right) \right]}{\prod_m^M \left[\exp\left(\frac{\partial \ln \mathbf{W}}{\partial \ln V^m} \beta^m \ln \hat{U}^m \right) \right]} \widehat{\mathbf{W}} \mathbf{W^0} \tag{A24}$$

Hence, to compute $\mathbf{W}^{NCC}$, we need the derivatives from Eq. (A16) along with data on relative changes in demand and supply shifters U^m along with parameter values for the respective elasticities β^m.

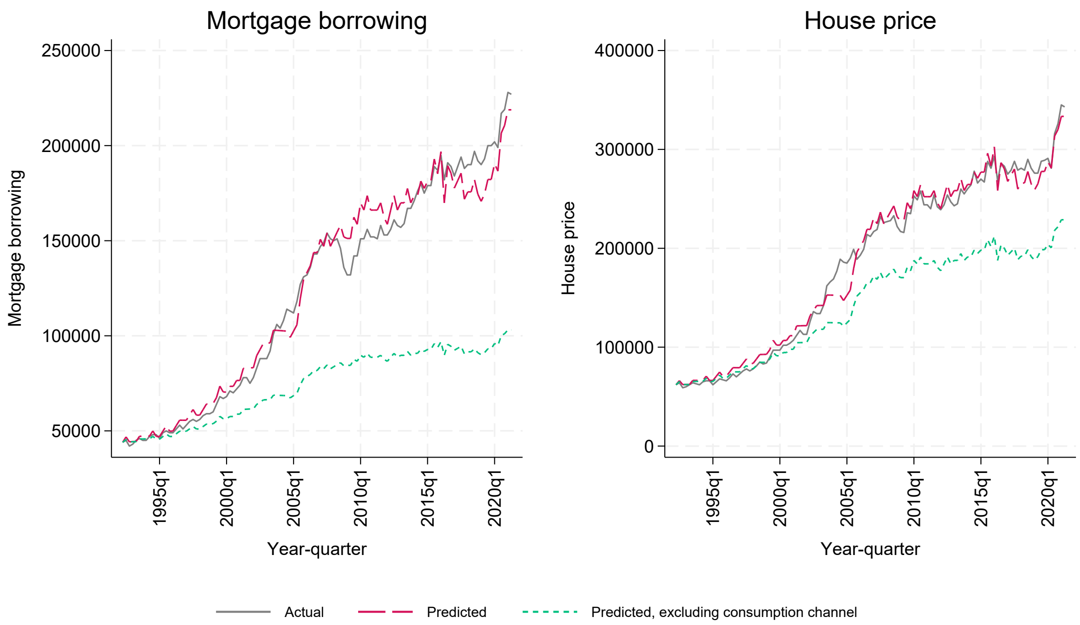
We choose the average gross income $U^{\mathcal{H}}$ as a shifter of housing demand $\tilde{\mathcal{D}}_H$ and the Bank of England central bank rate $U^{\mathcal{R}}$ as a shifter of credit supply $\tilde{\mathcal{S}}_L$ due to the robust evidence on their impacts (Jiménez et al., 2012; Carliner, 1973; Hansen et al., 1996). Our measure of income comes from the Regulated Mortgage Survey reported by the Office for National Statistics and gives the average income home buyers reported to lenders across the UK. Data on interest rates comes from the Bank of England and gives the base rate set by the bank. We define parameters $\{\beta^{\mathcal{D}_H}, \beta^{\mathcal{S}_L}\}$ that scale our predicted lending and house prices (based on income and base rates) to fit their values observed in the data and estimate these parameters using the GMM procedure. Specifically, we combine Eqs. (A20) and (A21) to formulate the following moment conditions:

$$\begin{aligned} &\mathbb{E}\left[\left(L_t - \exp\left(\frac{\partial \ln L}{\partial \ln \tilde{\mathcal{S}}_L}\beta^{\mathcal{R}} \ln \hat{U}_t^{\mathcal{R}}\right) \exp\left(\frac{\partial \ln L}{\partial \ln \tilde{\mathcal{D}}_H}\beta^{\mathcal{H}} \ln \hat{U}_t^{\mathcal{H}}\right) L^0\right) \hat{\mathbf{U}}_\mathbf{t}\right] = 0, \\ &\mathbb{E}\left[\left(n_t - \exp\left(\frac{\partial \ln n}{\partial \ln \tilde{\mathcal{S}}_L}\beta^{\mathcal{R}} \ln \hat{U}_t^{\mathcal{R}}\right) \exp\left(\frac{\partial \ln n}{\partial \ln \tilde{\mathcal{D}}_H}\beta^{\mathcal{H}} \ln \hat{U}_t^{\mathcal{H}}\right) n^0\right) \hat{\mathbf{U}}_\mathbf{t}\right] = 0 \end{aligned} \tag{A25}$$

where t indexes one of T quarters in our study period, 0 denotes the starting period and $\{\hat{\mathbf{U}}_\mathbf{t}\}$ is the vector of included instruments. Hence, $\{\hat{U}_t^{\mathcal{R}}, \hat{U}_t^{\mathcal{H}}\}$ give the relative change in a covariate from the initial period to period t. Eq. (A25) gives us two moment conditions that allow us identifying the two parameters $\{\beta^{\mathcal{R}}, \beta^{\mathcal{H}}\}$ using a GMM estimator with an unadjusted weights matrix using included instruments. Intuitively, we find the parameters that result in the best match between observed and predicted borrowing and house price trends.

As depicted in Figure A4, we predict observed trends in mortgage demand and house prices well under the identified parameter values; however the fit is almost identical to when we use just one arbitrary housing demand shifter (see Figure A3). The reason is that we obtain a $\beta^{\mathcal{H}}$ near one and a $\beta^{\mathcal{R}}$ that is near zero. The implication is that our model requires primarily exogenous income shocks to rationalize observed trends in endogenous outcomes over the study period.

Figure A4: Counterfactual trends: Demand and supply shifters



The solid lines present the actual trends observed in data. The long-dashed lines give predictions in presence of a consumption channel, computed according to Eq. (A20). The short-dashed lines gives predictions in the absence of a consumption channel, computed according to Eq. (A22). We use the $\{\omega\}$ from the all-buyer-type sample in Table 3, Column 3 in both predictions. For the predictions we use observed changes in income and central bank lending rates as exogenous housing demand and supply shifters. We chose parameters β^m such the obtain the best match between in the observed and predicted trends in endogenous variables.