The equilibrium effects of taxing property investors

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October 4, 2022

Abstract

Housing prices have seen an unprecedented increase in the UK in the last two decades, following an explosion of the buy-to-let sector. This paper aims to understand the impact of buy-to-let investors on housing prices and more generally on the housing market. First, I analyze the effects of a large and exogenous demand shock that directly affected buy-to-let investors but not home-movers and first-time buyers: a 3% stamp-duty surcharge applied on 'buyers of additional properties' introduced in April 2016. Using an incremental diff-in-diff estimator, I find that the surcharge had large and significant effects on the housing market, with an average decrease of 12.2% in the volume of property transactions and 1.67% in property prices, but no significant impact on housing supply within four years from its introduction. The impact appears to be amplified by the presence of search frictions in the housing market, as the surcharge increases time to sell by 3.3% on average. Based on this empirical evidence, I build a search model of the housing market to quantify the extent to which the large influx of buy-to-let investors since the late 1990s contributed to the large increase in UK real housing prices in the following two decades.

1 Introduction

Since the end of the last century housing prices have increased over and beyond inflation in almost all developed countries [Knoll et al., 2017]. The United Kingdom was no exception: from 1996 to 2019, housing prices have consistently outpaced average earnings, rising by 240% with respect to the Retail Price Index and by 291% with respect to the Consumer Price Index (Figure 1). They

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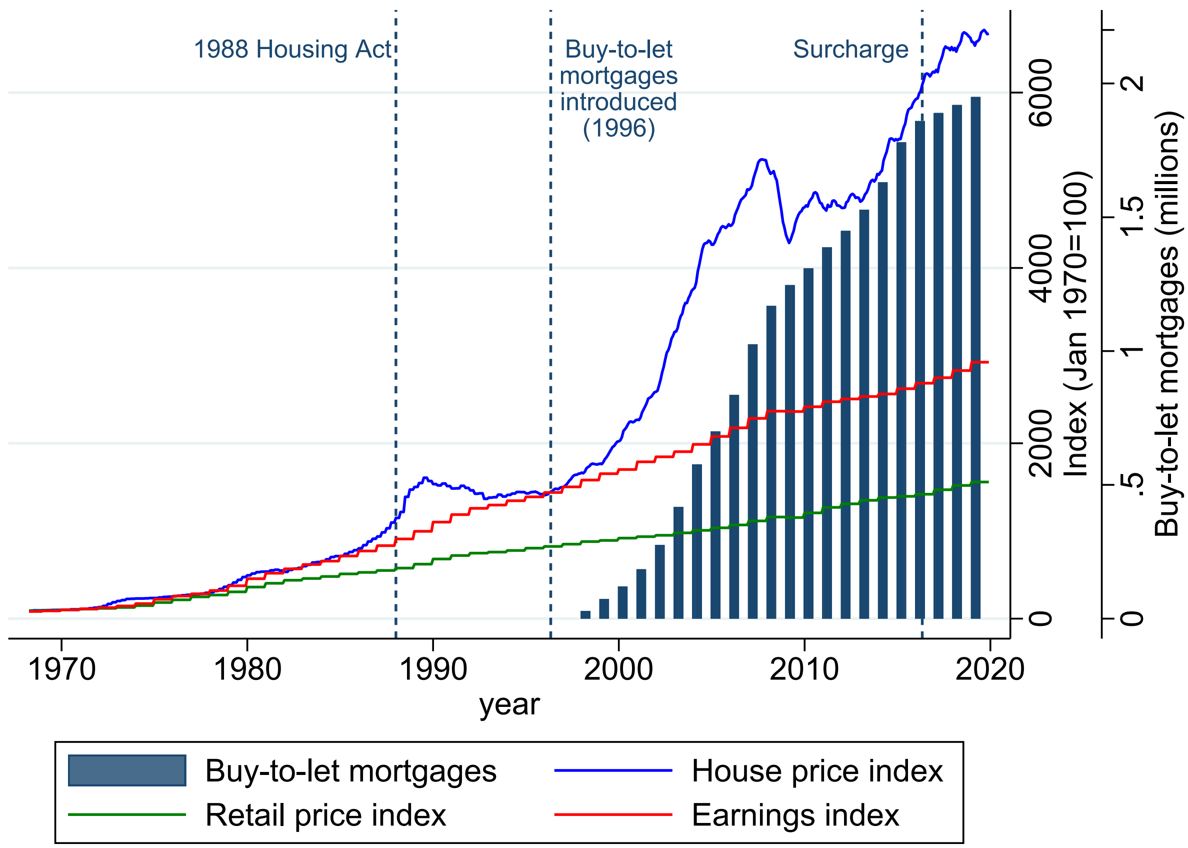
The data for this research have been provided by the Consumer Data Research Centre, an ESRC Data Investment, under project ID CDRC 604-02, ES/L011840/1; ES/L011891/1.

only temporarily declined during the Great Recession, to start rising again soon after (Appendix Figure D1).

Some argue that house prices are inflated by low interest rates due to loose monetary policy (e.g., Taylor, 2009). Others emphasize a reduction in down payment requirements as a primary driver of the boom (e.g., Favilukis, Ludvigson and Van Nieuwerburgh, 2017). A third view is that neither of these factors can realistically explain the extent of the boom, highlighting the potential role of overly optimistic expectations about future price gains in driving rapid house price appreciation (Glaeser, Gottlieb and Gyourko, 2013). My paper analyzes another potential driver: the unprecedented increase in investors due to a reduction in investors' credit frictions. Understanding the relevance of this factor is crucial not only to understand the past, but also to ensure housing market and financial stability in the future.

This unprecedented rise in housing prices followed a series of changes in the UK rental and credit markets: the liberalization of a heavily regulated private rental sector in 1988 and the creation of 'buy-to-let mortgages' in 1996. The increase in expected returns led to the explosion of buy-to-let investment. The number of outstanding buy-to-let mortgages raised from virtually none to almost 2 millions (Figure 1) and the share of privately rented properties doubled from 10 to 20% in two decades (Appendix Figure D3). A similar growth in the number of investors is a common feature of housing markets in most developed countries since the 1990s, thanks to low interest rates and financial deregulation [Martin et al., 2018].

Figure 1: The growth of housing prices and buy-to-let mortgages in the UK



To what extent investors are responsible for dramatic swings in housing prices? Central banks have expressed their concern that investors exacerbate housing market cycles by entering (exiting) the housing market when prices and rents are rising (falling) [Bank of England, 2016; Reserve Bank of New Zealand, 2016; Reserve Bank of Australia, 2017; De Nederlandsche Bank, 2018]. Governments and the media fear that investors' entry can increase property prices and crowd-out owner-occupiers, reducing the positive externalities associated with home-ownership [Dietz and Haurin, 2003; Wallop, 2011; HM Treasury, 2016]. On the other hand, investors can have a beneficial impact on the housing market by increasing real-estate liquidity and by stimulating housing supply [Bayer et al., 2011; Gao et al., 2020]. Yet further evidence is needed to determine the role of investors in the housing market. The simultaneous increase in the number of investors and prices might be a spurious correlation and the direction of causality is not clear without a quasi-experimental analysis.

This paper aims to understand to what extent the entry and exit of investors can affect the housing market, with a particular focus on housing prices. First, I analyze the impact of a large and exogenous demand shock that directly affected buy-to-let investors but not home-movers and first-time buyers: a 3% stamp-duty surcharge applied only on 'buyers of additional properties' introduced in the UK in April 2016. Since the surcharge was implemented in the UK simultaneously, I exploit the large degree of heterogeneity in the pre-policy share of private rented properties across UK local authorities as a measure of the 'bite' of the surcharge. Then, I use the incremental difference-in-differences estimator proposed by Card [1992] to identify the impact of the reduction in buy-to-let investors' demand on housing market outcomes.

I estimate that the surcharge had large and significant effects on the housing market, with an average decrease of 12.2% in the volume of property transactions and an average decrease of 1.67% in property prices, but no significant impact on housing supply within four years from its introduction. These estimates are large but comparable with previous measures of transfer-tax elasticities on volumes and prices [Best and Kleven, 2018; Kopczuk and Munroe, 2015]. As in [Kopczuk and Munroe, 2015], the impact appears to be amplified by the presence of strong search frictions in the housing market. The median seller takes 6 months to sell a property in England and Wales and the surcharge significantly increased time-to-sell by 3.3% on average. The reduction in the volume of property transactions and the increase in time-to-sell is consistent with a reduction in the ratio of buyers over sellers active in the market (market tightness) generating a self-reinforcing negative loop on prices which fell even more than the standard tax incidence response.

Based on these findings, the second part of the paper presents a search model of the housing market to quantify the extent to which the large influx of buy-to-let investors since the late 1990s contributed to the rapid increase in UK real housing prices in the following two decades. To account for amplification effects due to search frictions, the property market is characterized by search costs and a matching function à la Pissarides [2000]. Households and buy-to-let investors compete in the same property market, but they are heterogeneous in wealth and search for a mortgage in different credit markets.

Credit markets are imperfect and characterized by credit rationing. I model credit rationing by introducing a credit search cost and a credit matching function, in a symmetric way with respect to the property market. Characterization of the credit market via an aggregate matching function is in line with several empirical findings [Dell'Ariccia and Garibaldi, 2005; Petersen and Rajan, 2002] and allows to model credit market rationing in a tractable way. As the creation of buy to let mortgages reduced frictions in the credit market for investors, I allow for the efficiency of the credit matching function to increase over time in order to quantify its impact on prices. Given that observed average time-to-let a property is an order of magnitude lower than the time-to-sell, I assume that the rental price is endogenously determined by the model to clear instantaneously a frictionless rental market. Loan amounts and property prices are negotiated in a sequential Nash bargaining process to maximize the total surplus of mortgagors-sellers and buyers-sellers, respectively.

Using equilibrium equations and data on average prices, rents, number of mortgages, interest rates and loan-to-value ratios by type of buyer, the model generates a dramatic fall in investors' credit frictions and a relatively stable trend for households' credit frictions in the period 1996-2019, except for a temporary increase for both during the financial crisis of 2007-2009. Next, I will show how this fall in credit search frictions for investors led to a large entry of buy-to-let investors and to estimate the impact this had on housing prices. In a counterfactual analysis, I will simulate how housing prices would have changed if credit market efficiency in the buy-to-let sector were unchanged and whether tax policies as the stamp-duty surcharge increase total welfare.

Several papers have tried to quantify the determinants of housing booms, in particular the US housing boom preceding the Great recession. Sommer et al. [2013] and Kaplan et al. [2020] build incomplete markets models with heterogeneous agents and a rental sector. Sommer et al. [2013] show that a reduction in interest rates and down-payments can explain only half of the price increase and argue that most of the price increase must be due to overly optimistic expectations about house price growth. Similarly, Kaplan et al. [2020] argue that the main driver of movements in house prices and rents was a shift in belief. This occurs because when credit conditions are relaxed, some renters become home-owners but they do not substantially increase their consumption of housing services. home-ownership rate rise but not aggregate demand for housing or house prices.

These papers however do not account for the amplification effects of housing search frictions and do not focus on the role of investors. In Kaplan et al. [2020], buy-to-let investors buy and sell housing units without any credit friction and thus they cannot drive the price increase. Yet there is empirical evidence that investors played an important role in the US housing boom and bust. Haughwout et al. [2021] show that investors had almost half of mortgages in bubble states and notice a large increase in investors' mortgage share during the housing boom and in investors' defaults during the housing bust. Gao et al. [2020] find that states with more investors had stronger construction and economic expansion in 2004-2006 and sharper economic downturn in 2007-2009.

Other papers have tried to include search frictions in the housing market following the seminal work by Wheaton [1990] (see Han and Strange [2015] for a review). Among these, few focus on the role of investors. Han et al. [2021] find that a land transfer tax in Toronto induces a rise in buy-to-let transactions but a fall in owner-occupiers transactions, despite the tax applying to both. Contrary to my results, this unconditional transfer tax appears to *increase* the share of investors in the housing market. Their housing search model with property and rental markets predict a reduction in mobility within the property market and an increase in demand in the rental market which generates a fall in home-ownership rate. [Bø, 2021] develops a search model that allows housing owners to invest in rental housing and let rental price be determined endogenously. The model cannot be solved analytically and does not contain a credit market, but its calibration matches the high investor share and housing price increase of a housing boom after a positive population shock, without using over-optimistic expectations.

The contribution of this article is threefold. My paper contributes to the literature in several ways. While previous papers have analyzed the impact of transfer taxes that target unconditionally all buyers, little is known about the housing market response when the tax targets agents that do not purchase properties for housing consumption, but only for housing investment. My results have first-order relevance for policy-makers because increasing home-ownership without raising housing prices and discouraging housing supply is among the main objectives of current housing policies in many countries. Secondly, if investors' credit frictions are absent in Bø [2021], Sommer et al. [2013] and Kaplan et al. [2020], my paper explicitly models credit markets with frictions for both households and investors. Using credit matching functions à la Pissarides [2000], I can estimate general equilibrium effects on housing prices of a relaxation of credit access for investors in a tractable model that has intuitive implications. This modelling choice is not new to models that combine credit, labor and non-durable goods markets [Dell'Ariccia and Garibaldi, 2005; den Haan et al., 2003; Wasmer and Weil, 2004; Petrosky-Nadeau and Wasmer, 2013, 2015], but it is surprisingly novel for models of the housing market, in which access to credit plays a central role. To do this, I have constructed a property-transaction-level dataset that allows to identifies mortgage from outright transactions, buy-to-let from buy-to-live transactions and includes rich information on time to sell, listing prices and property characteristics by matching Land Registry sale records with Zoopla rental listings and Energy performance certificates. Using all this information, I can analyze the role of buy-to-let investors and their mortgage relaxation on the housing market.

The paper is organized as follows. Section 2 presents the SDLT surcharge and Section 3 describes the data used to analyze its impact on the housing market. Section 8 explains the identification strategy and Section 5 presents the results and the role of search frictions in the amplification of the effects. Section 6 illustrates the search model of the housing market with households and investors and Section 10 concludes.

2 Policy background

2.1 The explosion of buy-to-let investment

The explosion of the buy-to-let sector was triggered by a series of changes in the rental and credit markets at the end of the last century. Until 1988, tenants in the UK could appeal to rent officers to obtain a 'fair rent' and the 1977 Rent Act ensured a long-term security of tenure and restricted landlords' powers of eviction [Kemp, 2015]. The Housing Act 1988 liberalized the heavily regulated private rental sector. It allowed landlords to let properties at market rents. Moreover, it reduced to 2 months the minimum notice to evict and to 6 months the minimum tenancy tenure

[Housing Act, 1988].

Another push to the buy-to-let sector came from the credit market. Before 1996, loans for properties bought to let were mortgages based on the mortgagor's income with an additional risk premium of around 2% with respect to standard mortgage interest rates. As a consequence, buy-to-let mortgages were rather uncommon. In 1996, a panel of mortgage lenders in concert with the Association of Residential Letting Agents devised the 'buy-to-let mortgage': a new mortgage product based on expected rent with an interest rate close to the standard one for residential mortgages [Leyshon and French, 2009].

2.2 The Stamp-Duty Land Tax (SDLT) surcharge

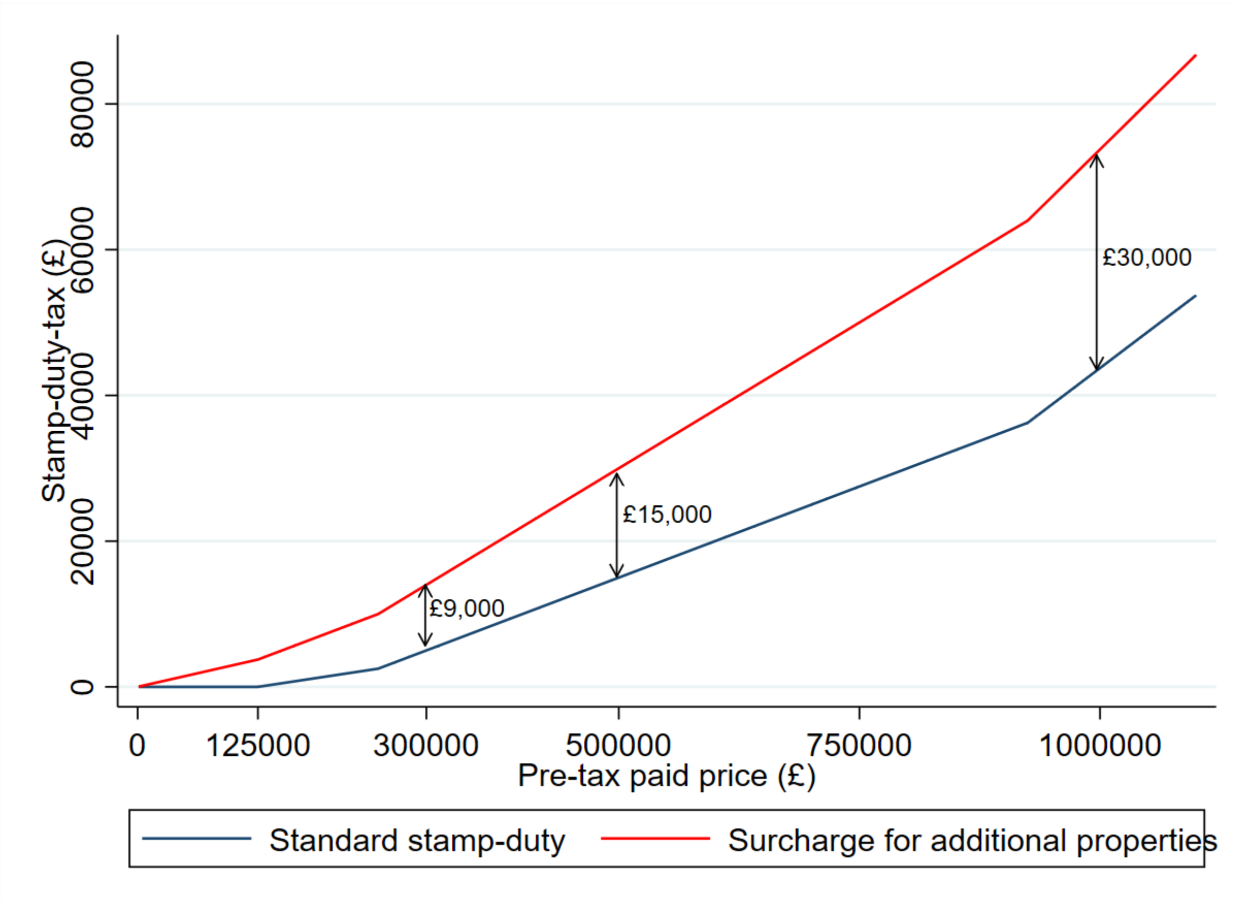
On 25 November 2015, Chancellor George Osborne announced a 3% Stamp-Duty Land Tax (SDLT) surcharge on purchases of additional properties as part of a Five-Point-Plan to support home ownership in the UK [HM Treasury, 2015, 2016]. The other points of the plan were: to deliver 400,000 affordable housing starts by 2020-21; to accelerate housing supply and get more homes built (e.g. by releasing public sector land); to prolong the already existing 'Help to Buy' Equity Loan scheme until 2021 and to create a London 'Help to Buy' scheme; to extend the 'Right to Buy' scheme to Housing Association tenants. In Section 5.2, I explain how I can isolate the effect of the surcharge from the other policies of the Five-Point-Plan and show that the main results stand when performing several robustness checks.

The SDLT is an ad-valorem transaction tax paid on every residential property transferred in England, Northern Ireland and Wales [Ministry of Housing, 2022a].[1] As we can see in Figure 2, the SDLT schedule presents several kinks as the marginal rate increases in the transaction price, starting from 0% of the portion of the transaction price below $\pounds 125,000$ up to 12% of the portion of the transaction price above $\pounds 1.5m$ in 2016.

The SDLT surcharge consists in an increase of 3 percentage points on the standard SDLT rates independently of the transaction price, but it applies only to buyers of additional properties. If the buyer owns more than one property after 18 months from the transaction, the surcharge applies. Accordingly, the SDLT surcharge applies to buy-to-let investors, buy-to-leave investors, real estate companies and second-home buyers, but does not apply to home-movers and first-time buyers. The diagram in Appendix Figure D5 specifies the liability of the SDLT surcharge in more detail.

[1] The Stamp Duty Land Tax (SDLT) became the Land Transaction Tax in Wales from 1 April 2018, but the tax schedule remained unchanged until December 2020.

Figure 2: Stamp-duty schedule



Notes: This Figure shows the SDLT tax schedule in 2015 ('Standard stamp-duty') and how it increased for buyers of additional properties in 2016 ('Surcharge for additional properties').

The SDLT surcharge was announced on November 25, 2015 and came into effect on April 1, 2016. As we can see in Appendix Figure D6, the period between the announcement and the implementation of the reform saw an increase in the volume of property transactions. Some buyers of additional properties appear to have anticipated their planned property transactions in order to avoid the transaction tax increase. Section 5 explains how I account for these anticipation effects in the analysis of the housing market impact of the SDLT surcharge.

3 Data

To analyze the impact of the SDLT surcharge on the housing market, I have geocoded and merged three datasets: the HM Land Registry Price Paid data, the Energy Performance Certificates (EPC) dataset and WhenFresh/Zoopla data provided by the Consumer Data Research Centre. The linking variable is the property address, which consists in the Primary Addressable Object Name (typically the house number or name), the Secondary Addressable Object Name (e.g. flat number), the street and the full postcode.

The Land Registry dataset contains the universe of residential property transactions occurred in the UK from 1995 to 2021. Each observation includes the property address, its coordinates, the transaction date, the price paid, and several property characteristics (e.g. whether the property is new/old, whether the property is a leasehold/freehold) [HM Land Registry, 2022].

The EPC dataset contains every energy performance certificate produced on sale or rent of a building from October 2008 to December 2021. Each certificate reports the property address, the certificate date, a richer set of property characteristics (e.g. floor area size, energy efficiency rate) and the type of tenure (private rented, public rented or owner-occupied) [Department for Levelling Up, Housing and Communities, 2022a].[2] To merge this dataset with the Land Registry dataset, I use the certificate that has the closest date to the property transaction date.[3] To identify transactions in which buyers are buy-to-let investors, I focus on properties that have an Energy Performance Certificate *after* the transaction that identify them as privately rented. To identify transactions in which buyers are owner-occupiers, I focus on properties that have the an Energy Performance Certificate *after* the transaction that identify them as owner-occupied.[4]

The WhenFresh/Zoopla data includes information on all properties listed to sell and to rent on Zoopla, the second most popular property website in the UK, that were sold in the period 2014-2019 and were listed in the period 2012-2019. For each property, we can observe the listing dates for sales and lets, the listing price, the listing rental price, the transaction date, the starting tenancy date and additional of property characteristics (e.g. listed number of bedrooms/batrooms)[Consumer Data Research Centre, 2020a,b].

I use several other datasets for the regression covariates at local authority levels. For population and GDP per capita in each local authority, I use annual estimates provided by the ONS [2021a,b,c]. To account for the outcome of the Brexit referendum, I also control for the population share with EU nationality in each local authority in 2015, which is obtained from the Annual Population Survey [ONS, 2015], and the share of properties owned by EU companies in each local authority in October 2015 [HM Land Registry, 2022]. They aim to account for changes in demand for

[2]The EPC register does not hold data for every domestic and non-domestic building, but only for those buildings for which an energy performance certificate was required in the period 2008-2021. After September 2008, lodging the data became a mandatory requirement and a building must have a valid EPC when constructed, sold or let. An EPC is valid for 10 years. The holder of an energy certificate can opt out of data disclosure, but only from a future data release.

[3]The algorithm for merging the Land Registry and EPC dataset was kindly shared by professor Hans Koster and professor Edward Pinchbeck. For details on this algorithm, I refer to their paper [Koster and Pinchbeck, 2022].

[4]This approach is different from Bracke [2021] who identifies buy-to-let purchases as transactions where a Zoopla rental advertisement follows a sale on the same property during the following six months. Since he does not identify all buy-to-let transactions, he cannot identify properties that are purchased by owner-occupiers.

properties by population and firms, respectively, due to the expectation of withdrawal from the EU. For council total and housing expenditures, I use data from the Department for Levelling Up, Housing and Communities and the Welsh government [Department for Levelling Up, Housing and Communities, 2022b; Welsh Government, 2021a,b].

Finally, for model calibration I also use aggregate UK annual data in 2015, the year before the surcharge was introduced. This includes administrative data on the housing stock, the housing flows, the vacant stock [Ministry of Housing, 2022b], the number of outstanding residential and buy-to-let mortgages [Ministry of Housing, 2014; Council of Mortgage Lenders, 2022].

4 Empirical strategy

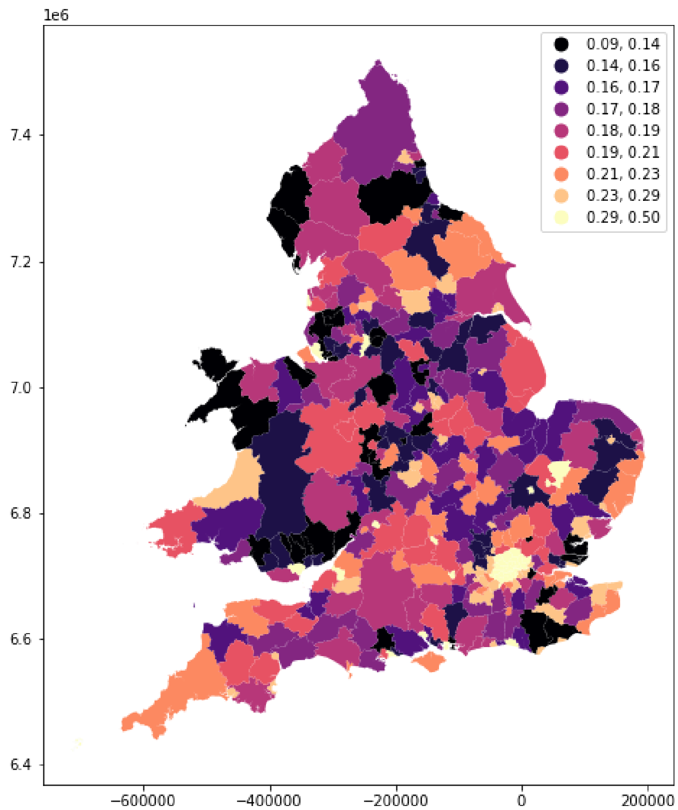
I analyze the role that buy-to-let investors have in the housing market by exploiting the exogenous demand shock caused by the SDLT 3% surcharge stamp-duty tax, which does not apply to home-movers and first-house buyers. The surcharge was implemented in the UK simultaneously at a homogeneous rate across property prices.[5] This precludes the possibility to exploit discontinuities in tax liability at threshold property prices as in Best and Kleven [2018]; Kopczuk and Munroe [2015]. Instead, my analysis is based on the incremental difference-in-differences estimator suggested by Card [1992] and exploits the heterogeneous degree to which local housing markets are affected by the SDLT surcharge.[6]

Local authorities in England and Wales present a high and longstanding geographic variation in buy-to-let investment. As we can see in Figure 3, the share of properties that were privately rented in 2008-2015 ranged from 9.5% in the Welsh county borough of Torfaen to 50.4% in the City of London district. This variation implies that the SDLT surcharge affects local authorities to different intensities. The larger the private rental sector in a local authority, the stronger the 'bite' of the surcharge in that local housing market because buy-to-let investors have to pay the surcharge, whereas home-movers do not.

[5] The surcharge was increased to 4% in Scotland from 25 January 2019 and in Wales from 22 December 2020.

[6] See Dolton et al. [2010] and Caliendo et al. [2018] for more recent applications.

Figure 3: Share of private rented properties by local authorities in 2008-2015



Notes: This heat map of England and Wales shows the share of private rented properties by local authorities using Energy Performance Certificate data from 2008 to 2015. The legend reports the range of the share of private rented properties corresponding to each color.

I use the share of private residential properties that were privately rented according to Energy Performance Certificate data from 2008 to 2015 in local authority j as a measure for the SDLT surcharge bite. Then, I apply an incremental difference-in-difference estimator to analyse the impact of the surcharge on number of property transactions, prices and housing supply within four years (2016-2019).

For each property i, local authority j and quarter t, I estimate the following regression equation:

$$\begin{aligned} y_{ijt} = & \gamma_j + \eta_t + \theta_t Rented_{j,2015} + \psi_t Second_{j,2015} + \lambda_t London_j \\ & + \phi_t EUcom_{j,2015} + \rho_t EUpop_{j,2015} + \beta X_{ijt} + \zeta Z_{jt-1} + v_{ijt} \end{aligned} \tag{1}$$

Equation (1) is estimated for housing market outcomes y_{ijt} at property transaction level (e.g. prices). For housing market outcomes at local authority level (e.g. number of transactions), I use the same regression specification excluding property-level controls.[7] where γ_j are local authority fixed effects and η_t are quarter fixed effects. X_{ijt} is a vector of property-level characteristics which includes quadratics in latitude and longitude, the property size, the number of rooms, the property energy performance, the type of property (detached, semi-detached, terraced or flat), an indicator for a new property, leasehold/freehold, the presence of a fireplace, type of wall, the presence of property extensions. Z_{jt-1} is a vector of local-authority covariates lagged by one year, which includes the local authority population, GDP per capita, housing stock, council total expenditures, council housing expenditures and the (band-D) council tax amount. v_{ijt} is an error term. $\lambda_t London_j$ are London-by-quarter fixed effects to control for differential effects in London with respect to the rest of the country and the introduction of the London 'Help to Buy' scheme. $Second_{j,2015}$ is the share of second homes in local authority j in 2015.[8] $\psi_t Second_{j,2015}$ controls for the impact of the tax on second-home buyers and buy-to-leave buyers in each quarter t. $EUpop_{j,2015}$ is the share of residents with a EU nationality and $EUcom_{j,2015}$ is the share of properties owned by EU companies in local authority j in 2015. $\rho_t EUpop_{j,2015}$ and $\phi_t EUcom_{j,2015}$ control for the potential impact that the Brexit announcement following the result of the referendum on 23 June 2016 may have had on housing demand by EU citizens and companies.

The vector of coefficients θ_t are the incremental difference-in-differences coefficients of interest, which capture the average effects of the surcharge on buy-to-let investors in each quarter relative to the default period of the sample (the quarter before the surcharge announcement). Since these coefficients are quarter-specific and includes quarters before the policy announcement, we can check for the presence of pre-policy trends which would invalidate the empirical analysis.

Finally, to analyze the overall impact of the surcharge over the the years 2016-2019, I estimate the following regression equations:

$$\begin{aligned} y_{ijt} =& \gamma_j + \eta_t + \theta Post_t * Bite_{j,2015} + \psi Post_t * Second_{j,2015} + \lambda Post_t * London_j \\ &+ \phi Post_t * EUcom_{j,2015} + \rho Post_t * EUpop_{j,2015} + \beta X_{ijt} + \zeta Z_{jt-1} + v_{ijt} \end{aligned} \tag{3}$$

Equation (3) is estimated for housing market outcomes y_{ijt} at property transaction level. For housing market outcomes at local authority level, I use the same regression specification excluding

[7]For housing market outcomes y_{jt} at local authority level the regression equation is:

$$\begin{aligned} y_{jt} =& \gamma_j + \eta_t + \theta_t Rented_{j,2015} + \psi_t Second_{j,2015} + \lambda_t London_j \\ &+ \phi_t EUcom_{j,2015} + \rho_t EUpop_{j,2015} + \zeta Z_{jt-1} + v_{jt} \end{aligned} \tag{2}$$

[8]For Wales, data on second homes is absent. In its place, I use the local-authority share on homes without a usual resident from the 2011 census [Office for National Statistics, 2011]

property-level controls.[9] The coefficient of interest here is θ and $Post_t$ is a binary variable equal to 1 for each quarter since the introduction of the surcharge and 0 otherwise. θ can be interpreted as the change in the dependent variable (e.g. log prices) for a 3% stamp-duty surcharge increase if all properties were buy-to-let properties. This is because the coefficient θ captures the change in outcomes after the surcharge for a local authority with all properties that are buy-to-let properties $Bite_{j,2015} = 1$ with respect to a local authority without any buy-to-let properties $Bite_{j,2015} = 0$. The interactions $Post_t * Second_{j,2015}$, $Post_t * London_j$, $Post_t * EUcom_{j,2015}$ and $Post_t * EUpop_{j,2015}$ control for: the impact of the surcharge on second-home buyers; differential trends in London; changes in housing demand by EU companies; changes in housing demand by EU citizens, respectively, in the entire post-policy period.

I restrict the regression sample to the period October 2013-December 2019. This is because the Land Registry Price-Paid dataset includes buy-to-let transactions only from October 2013 and because the WhenFresh/Zoopla dataset is available only up to 2019. Moreover, stopping the analysis at the end of 2019 avoids potential confounding factors such as the withdrawal agreement from the EU formalized in January 2020 and the insurgence of the COVID-19 pandemic in February 2020. I use standard errors clustered at local authority levels in all regressions. For regressions at property-level that might be heavily affected by spatial correlation, I also allow for spatial correlation within $100km$ from the local authority using Conley [1999]'s heteroskedasticity and autocorrelation-consistent standard errors.

The choice of what constitutes a local housing market is open to discussion. Since local housing policies (e.g. council tax) are determined at local authority level (county councils, district councils, unitary authorities, metropolitan districts, London boroughs), the natural choice is to have local authorities as the main geographical units. In 2011, there were 348 local authorities in England and Wales: 36 Metropolitan Districts, 201 Non-Metropolitan Districts, 31 London Boroughs and 54 Unitary Authorities in England, as well as 22 Unitary Authorities in Wales.[10]

5 Results

In this Section, I analyze how the surcharge affected multiple aspects of the housing market in England and Wales. In Section 7, I will show that an equilibrium model of the housing market

[9]For housing market outcomes y_{jt} at local authority level the regression equation is:

$$\begin{aligned} y_{jt} =& \gamma_j + \eta_t + \theta Post_t * Bite_{j,2015} + \psi Post_t * Second_{j,2015} + \lambda Post_t * London_j \\ &+ \phi Post_t * EUcom_{j,2015} + \rho Post_t * EUpop_{j,2015} + \zeta Z_{jt-1} + v_{jt} \end{aligned} \tag{4}$$

[10]In 2019 some local authorities changed and new local authorities were created. Address geocoding allows to maintain the boundaries of the local authorities fixed at the 2011 boundaries throughout the entire sample period and to assign each property to a fixed spatial unit.

with search frictions is able to capture qualitatively all the main effects of the surcharge.

Table 1 shows the estimates of the impact of the surcharge on the log number of quarterly property transactions at local authority level. In column (1), I estimate the coefficient θ in (4) without local authority controls (Z_{jt-1}), which are added in column (2). In column (3), I control for anticipation effects by adding the interaction $Ant_t * Bite_{j,2015}$ in which Ant_t is a binary variable equal to 1 in the quarter between the announcement and the introduction of the surcharge and 0 otherwise. In column (4), I estimate the coefficient θ in (3) using a donut hole approach: I test whether dropping all property transactions within 6 months before and after the introduction of the surcharge significantly changes the estimates. In column (5) I add the interactions $Post_t * EUcom_{j,2015}$ and $Post_t * EUpop_{j,2015}$ to account for the potential effects of the Brexit referendum.

Table 1: Effect of stamp-duty surcharge on log number of quarterly property transactions

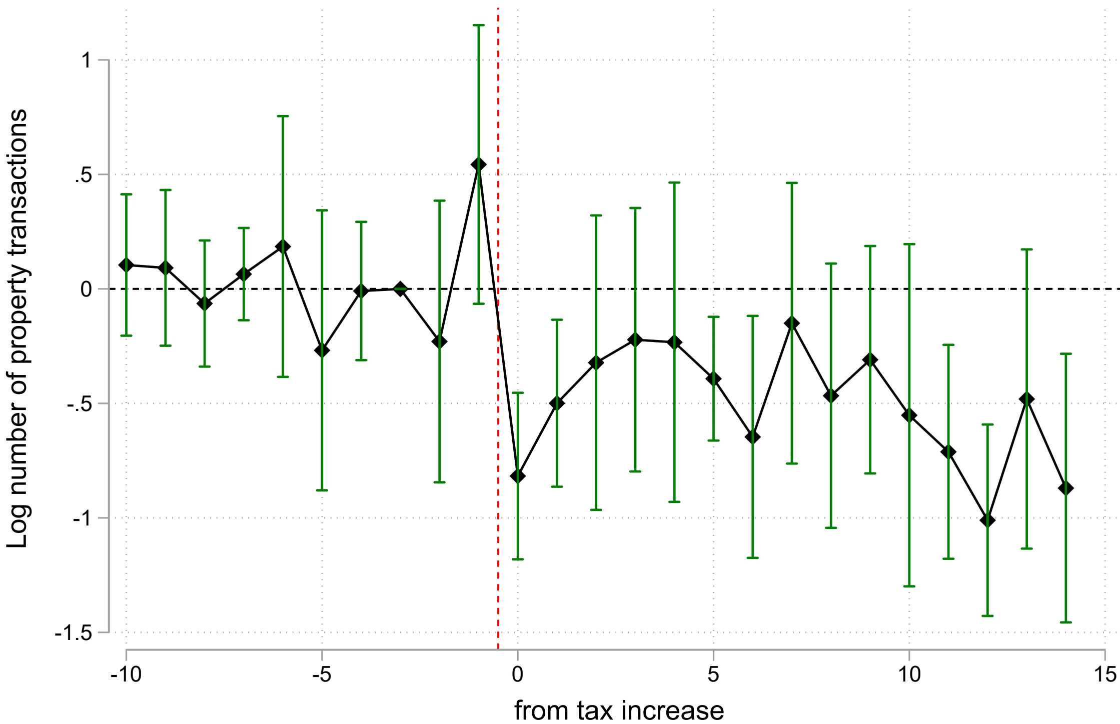
	(1)	(2)	(3)	(4)	(5)
Post*Share Rented	-0.597***	-0.655***	-0.489***	-0.591***	-0.502**
	(0.146)	(0.145)	(0.188)	(0.196)	(0.242)
Ant.*Share Rented			0.600***		
			(0.189)		
N	8,700	8,700	8,700	7,308	7,308
LA controls	NO	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES
Post*London	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA

Notes: This table reports results from OLS regressions of Equation (4) using the log of the number of days between the transaction date and the listing date as the dependent variable. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

The estimates for θ range from -0.502 to -0.655 and are robust to every specification: the surcharge significantly reduces the volume of transactions in local authorities in which the buy-to-let market is larger (p-value< 0.05). The estimates for θ in columns (3), (4) and (5) are only slightly lower than the estimate in column (2), showing that anticipation effects or the Brexit referendum do not appear to be the main drivers of the policy impact on transactions.

These estimates can be interpreted as the percentage change in transactions for a 3% stamp-duty surcharge increase if all properties were buy-to-let properties. The estimated elasticity of the number of transactions with respect to the tax is $-0.502/0.03 = 16.7$, which is large but in the ballpark of previous estimates. Best and Kleven [2018] analyze the impact of a UK stamp-duty holiday in 2008-9 on the number of transactions and estimate a short-run elasticity of -20.62 and a long-run elasticity of -14.3. Considering that only 20.35% of the properties were rented, the average impact of the 3% surcharge on English and Welsh local housing markets was a 10.2% decrease in the volume of property transactions over 2016-2019.[11].

Figure 4: Quarterly effect on log-number of transactions



Notes: This figure reports point-estimates and 95% confidence intervals for θ_t from the OLS regression of Equation (1) using the log number of transactions as the dependent variable. The horizontal axis shows the number of quarters from the introduction of the 3% surcharge.

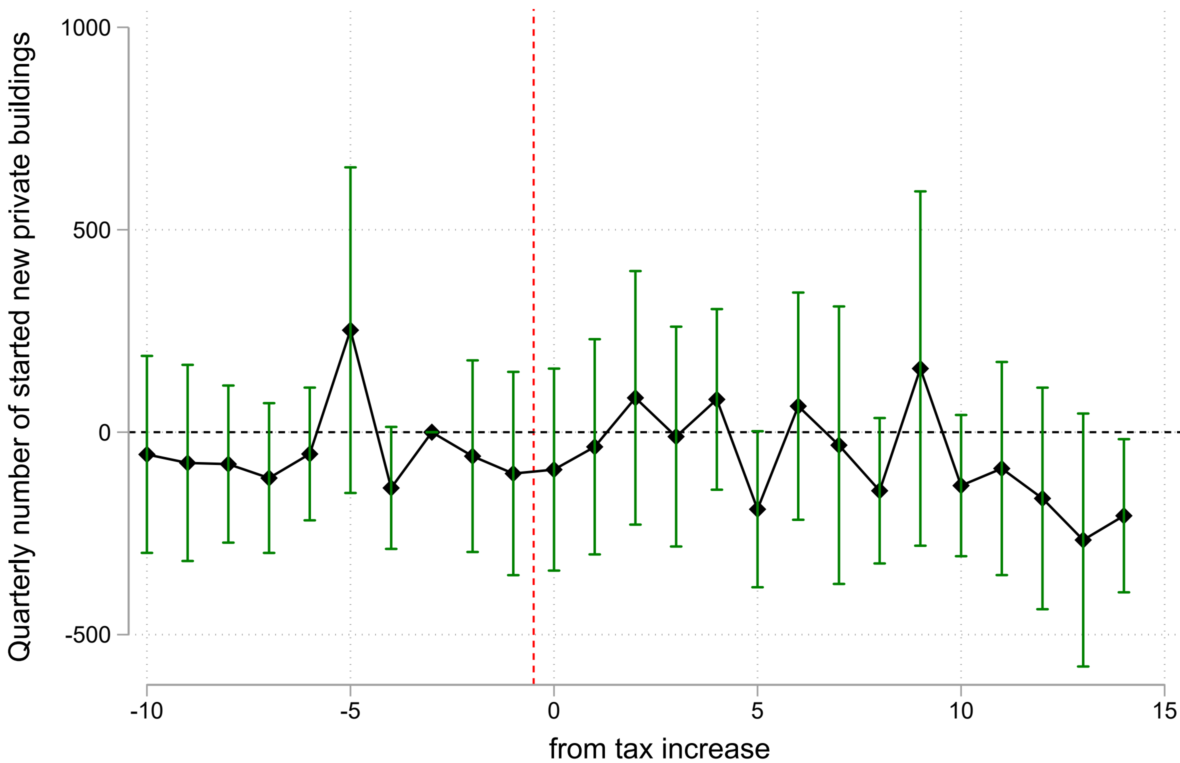
Figure 4 shows estimates of θ_t from regression Equation (1) on the log number of transactions and can be regarded as a test for the parallel trend assumption. Reassuringly, there is no clear trend before the introduction of the surcharge: pre-policy effects are never significant except for the significantly positive one in the anticipation period. Expectedly, the estimate for the coefficient in the quarter after the announcement and before the introduction of the surcharge is significantly positive, showing evidence that some buyers anticipated a property purchase before the introduction of the surcharge. On the other hand, the quarterly estimates are negative in all quarters after the introduction of the surcharge and significantly negative in half of them.

As the negative demand shock (the surcharge) led to a fall in property transactions, we would

[11] Using the last specification in Table 1, we have $-0.502 * 0.2035 = -10.2\%$

expect transaction prices to decrease as long as housing supply is not perfectly elastic. In the UK, Malpezzi and Maclennan [2001] estimate a long-run price elasticity of supply of new residential construction between 0 and 1, so housing supply appears to be on average relatively inelastic in the UK. Indeed, Appendix Table C2 and Figure 5 shows no significant response in the construction of new private buildings within 4 years from the introduction of the surcharge.[12]

Figure 5: Quarterly effect on new private buildings



To analyze the impact of the surcharge on prices, it is necessary to account for the extensive margin response on the number of transactions which might cause a selection bias. In particular, the surcharge might have disproportionately dissolved transactions for properties of higher (lower) quality than average. To account for this, I control for the rich set of property-level characteristics described in Section 4 with the addition of the *listing* price in Zoopla, which can be regarded as a measure of house quality according to the seller's evaluation of the property value. Importantly, in Appendix Table C6 and Appendix Figure D8, we see that sellers did not significantly change the *listing* price of properties (listed on Zoopla) in response to the surcharge. Therefore, the listing price can be used as a control for house quality in the regressions on paid prices.[13]

[12]The response of construction is likely to be delayed and thus we cannot rule a response in the longer term.

[13]Estimates remain significantly negative and of a similar magnitude if I do not include the listing price as a control.

The results are shown in Table 2. The estimates for θ range are significantly negative in every specification. In column(6), the standard errors adjusted for spatial correlation are lower than the clustered ones originally calculated, which is common in longitudinal studies with fixed effects [Kelly, 2020].[14] The estimate becomes larger in magnitude when we control for local authority characteristics that are likely to affect house prices (e.g. the council tax) and then remains stable around -0.1 after accounting for anticipation effects and the shares of EU residents and companies (p-value$<$ 0.01). Interestingly, as we can see in Figure 6, the quarterly effects on paid prices are around 0 until the introduction of the surcharge, and they become gradually more negative and significant over time. The fact that the impact on prices accrues over time cannot easily be explained by a purely static tax incidence argument. Instead, they are consistent with the presence of amplifying equilibrium effects that take some time to develop.

Table 2: Effect of stamp-duty surcharge on log paid price

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	-0.060***	-0.094***	-0.091***	-0.097***	-0.112***	-0.112***
	(0.022)	(0.017)	(0.017)	(0.019)	(0.022)	(0.020)
Ant.*Share Rented			0.025***			
			(0.009)			
N	1,950,769	1,950,769	1,950,769	1,590,874	1,590,874	1,590,874
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

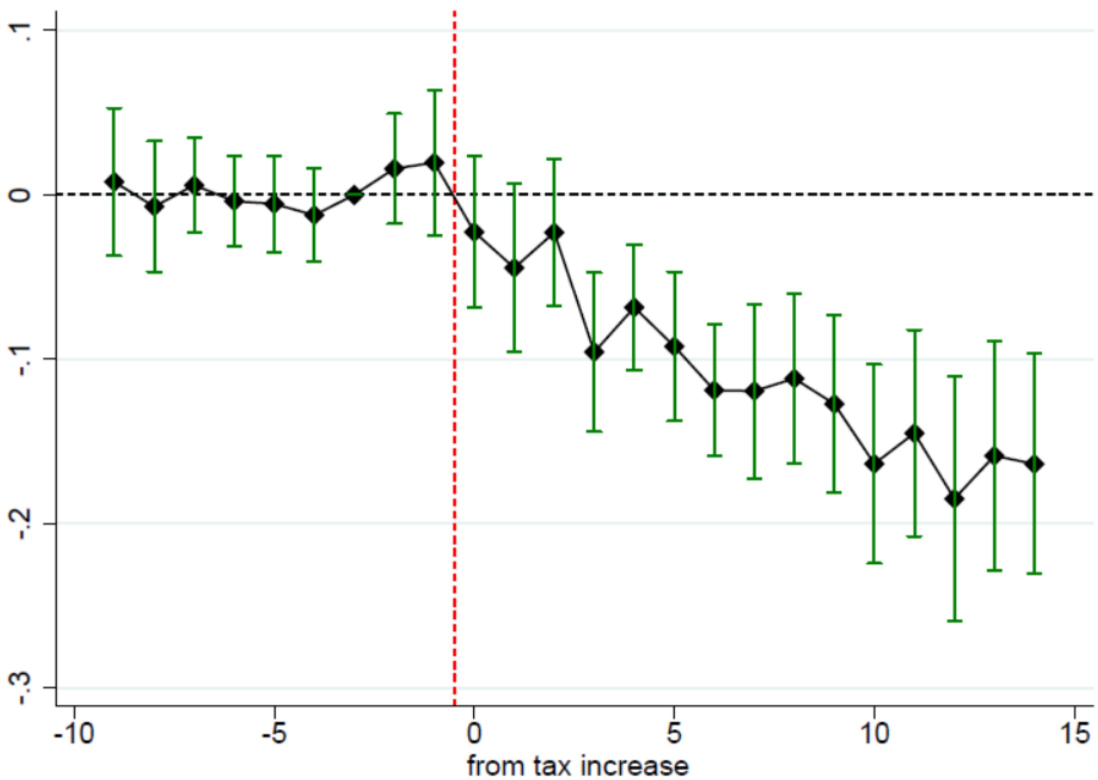
Notes: This table reports results from OLS regressions of Equation (3) using the log paid price as the dependent variable. Controls (property level): log listing price, quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

The estimates in Table 2 can be interpreted as the percentage change in paid prices for a 3% stamp-duty surcharge increase if all properties were buy-to-let properties. Considering that only 20.35% of the properties were rented, the average impact of the 3% surcharge on English and Welsh local housing markets was a 2.27% decrease in property prices over 2016-2019.

[14] Kelly [2020] argues that fixed effects already absorb a large degree of the spatio-temporal structure of the residuals and 'clustering is an aggressive solution to a problem that has substantially dissipated'.

Given the large degree of heterogeneity of the surcharge bite, the impact of the SDLT surcharge vary substantially across local authorities. Appendix Figure D7 shows that in areas as London, where the buy-to-let market is stronger, the surcharge reduces the number of transactions by as much as 22% and prices by as much as 4%.

Figure 6: Quarterly effect on paid price



5.1 How the SDLT surcharge affected the search process

The estimated elasticity of prices with respect to the tax is -3.3. This large value is not far from estimates in previous studies that study similar tax variations. Kopczuk and Munroe [2015] analyze the impact of transfer taxes on property prices in New York and New Jersey and estimate a range of tax elasticities of prices around -2.5.

Transaction taxes appear to be overshifted on property prices. Overshifting (a tax elasticity of prices larger than one) is not possible in a perfectly competitive and frictionless market [Fullerton and Metcalf, 2002]. Moreover, [Delipalla and Keen, 1992] show that ad valorem taxes such as the SDLT are less likely to lead to overshifting than unit taxes in imperfectly competitive markets. A potential explanation for this puzzling result is proposed by Kopczuk and Munroe [2015]. They show that the volume of missing transactions above the transfer tax notch they study exceeds the volume of transactions bunching below the notch, even after controlling for the usual extensive-margin response. They argue that the excessive market unravelling is present because of search frictions in the housing market: sellers may opt out or continuing waiting (by foregoing selling altogether or renting), or buyers may prefer to continue searching in order to benefit from locally depressed prices. To substantiate their claim, they find evidence that the tax notch disrupt the search process: the relationship between listing and paid price weakens (the final discount increases); the variance of paid prices conditional on property characteristics increases; the probability of selling for a listed property diminishes.

Demand or supply shocks to housing market fundamentals are amplified by search frictions through self-reinforcing feedback loops [Novy-Marx, 2009]. For instance, a negative demand shock (as the SDLT surcharge) brings less house buyers into the market. In presence of search frictions, buyers who stay in the market buy more quickly, reducing the stock of buyers in the market. Accordingly, sellers take more time to sell and this further increases the relative number of sellers to buyers, amplifying the initial shock. This impacts prices which can fall more than fundamentals.

Table 3: Effect of stamp-duty surcharge on log days to sell

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	0.166	0.258**	0.269**	0.315***	0.284*	0.284**
	(0.112)	(0.103)	(0.105)	(0.121)	(0.147)	(0.127)
Ant.*Share Rented			0.080*			
			(0.041)			
N	1,994,783	1,994,783	1,994,783	1,628,019	1,628,019	1,628,019
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

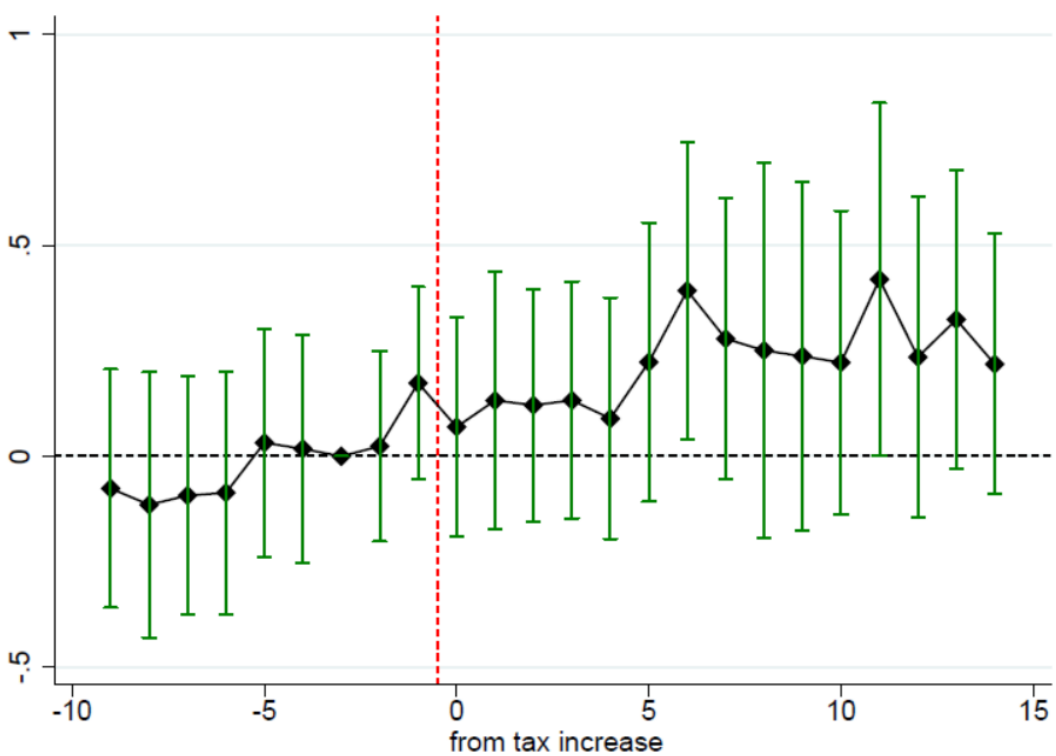
Notes: This table reports results from OLS regressions of Equation (3) using the log of the number of days between the transaction date and the listing date as the dependent variable. Controls (property level): quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

The mere coexistence of an inventory of houses for sale and a stock of potential buyers indicates the presence of search frictions in the housing market, which appear to be substantial in England

and Wales. Figure 8 shows that the median number of days to sell a property is 180 and the average number of days to sell a property is 331 for the sample of properties listed on Zoopla in 2012-2019. We have already seen that the discount from initial listing to paid price widens after the introduction of the SDLT surcharge (Table 2 and Figure 6).

To test whether the surcharge further affected the search and matching process, we can estimate whether it had a significant impact on the time it takes to sell a property. Table 3 show estimates of θ in regression (3) using the log number of days between the listing date and the transaction date. The surcharge increases time to sell in all specifications with and is statistically significant after adding controls at the local authority level. Using the last specification and considering that only 20.35% of the properties were rented, the average impact of the 3% surcharge on English and Welsh local housing markets was a 5.7% increase in the average time to sell a property.[15]

Figure 7: Effect on log days to sell



The interaction between the surcharge on investors and search frictions has important consequences from a welfare perspective. In particular, we can analyze whether the surcharge on multiple-property investors had an effect on the price paid by owner-occupiers who should not be directly affected by the surcharge.[16]. In a perfectly competitive and frictionless market, investors

[15]This result is confirmed by the analysis of quarterly effects in Appendix Figure 7: time-to-sell gradually increases and becomes significantly higher one year after the introduction of the surcharge.

[16]Only owner-occupiers that bought their current home as a second home are liable to pay the surcharge.

should bear the burden of the surcharge as sellers can always find a owner-occupier that buys the property without having to pay the surcharge. In Tables 4 and 5, we see that the surcharge had a stronger impact on the price of transactions in which the buyer is a buy-to-let investors relative to transactions in which the buyer will be an owner-occupier. Nonetheless, thanks to the surcharge on investors, owner-occupiers paid a significantly lower price. The effect on them is meaningful: on average their price decreased by 0.9-2.1% depending on the specification, compared to a decrease of 1.7-2.7% for buy-to-let investors.

All the evidence gathered in this section highlights the importance of the role of investors in the determination of prices in the housing market, whose volatility is amplified by the presence of frictions in the housing search process. The last finding reveals that a surcharge on multiple-property investors can help first-home buyers and home-movers purchase a property at a more affordable price. The model in Section 6 and the comparative statics analysis in Section 7 illustrates the mechanisms behind this indirect effect.

Table 4: Effect of stamp-duty surcharge on log price paid by owner-occupiers

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	-0.045**	-0.078***	-0.076***	-0.085***	-0.102***	-0.102***
	(0.021)	(0.016)	(0.016)	(0.019)	(0.022)	(0.021)
Ant.*Share Rented			0.022**			
			(0.010)			
N	1,226,749	1,226,749	1,226,749	978,144	978,144	978,144
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log listing price as the dependent variable. Controls (property level): log listing price, quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5: Effect of stamp-duty surcharge on log price paid by buy-to-let investors

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	-0.085***	-0.121***	-0.117***	-0.122***	-0.135***	-0.135***
	(0.024)	(0.018)	(0.019)	(0.021)	(0.025)	(0.023)
Ant.*Share Rented			0.031**			
			(0.015)			
N	342,803	342,803	342,803	283,801	283,801	283,801
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log listing price as the dependent variable. Controls (property level): log listing price, quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

5.2 Robustness checks

The 3% Stamp-Duty Land Tax (SDLT) surcharge on purchases of additional properties was part of a Five-Point-Plan to support home ownership in the UK [HM Treasury, 2015, 2016]. The other points of the plan were: to deliver 400,000 affordable housing starts by 2020-21; to accelerate housing supply and get more homes built (e.g. by releasing public sector land); to prolong the already existing 'Help to Buy' Equity Loan scheme until 2021 and to create a London 'Help to Buy' scheme; to extend the 'Right to Buy' scheme to Housing Association tenants.

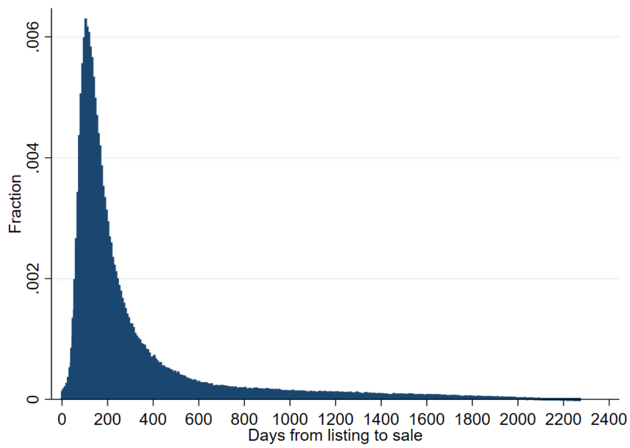
These factors would bias the estimates of the impact of the SDLT surcharge if their effects were correlated with the share of private rented properties. To account for this, I run several robustness checks. Regarding the first two points, I do not observe any differential impact in terms of housing supply, using changes in the construction of new private buildings as a dependent variable in the main regressions (Appendix Table C2 and Figure 5). The creation of the London 'Help to Buy' scheme is controlled for in the main regressions by including the interaction of the region London with quarter-fixed effects. The extension of the 'Right to Buy' scheme to Housing Association tenants was never rolled-out at a national level, but only through a pilot in the Midlands in August 2018. Appendix Tables C3-C9 show that controlling for the interaction of the region Midlands with an indicator of the period after the introduction of the 'Right to Buy' scheme does not qualitatively affect the main results.

6 The model

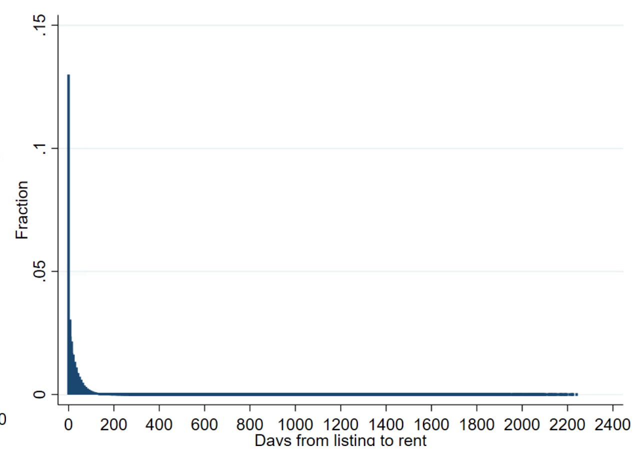
This section presents a random search-and-matching model of the property, rental and credit market markets. The aim of the model is to study to illustrates the mechanisms behind the effects discussed in Section 5.

The property market is characterized by search frictions: it is costly and time-consuming to search for a house to buy and it is costly and time-consuming to sell a house. For simplicity, the rental market is assumed to be frictionless. This simplification is based on the empirical evidence that it takes a substantially lower amount of time to let than to sell a property. As we can see in Figure 8, for the sample of properties listed on Zoopla, the median number of days to sell a property is 180, whereas the median number of days to let a property is 20,[17]

Figure 8: Evidence of search frictions in the property and rental markets.



(a) Days to sell: median=180; mean=331



(b) Days to let: median=20; mean=50

To understand the impact of the reduction of credit frictions on housing prices, credit markets for households and investors are assumed to be imperfect and characterized by credit rationing. I model credit rationing by introducing a credit search cost and a credit matching function, in a symmetric way with respect to the property market.[18] This modelling choice is not new to models

[17]Time-to-sell is measured as the number of days between the listing date on Zoopla as a property for sale and the transfer date on the Land Registry. Time-to-let is measured as the number of days between the listing date on Zoopla as a property to let and the starting date of the tenancy period recorded on Zoopla.

[18]The presence of credit rationing can be micro-founded in a model of asymmetric information between lenders and borrowers, as in [Stiglitz and Weiss, 1981]. The reason of excess demand equilibria in credit markets is that the higher the interest rate set by the bank, the riskier the borrowers that are willing to get a loan (adverse selection) and/or the riskier the projects they will engage in (moral hazard). Non-monotonicity of profits in the interest rate can result in a profit-maximizing equilibrium interest rate that is lower than the market-clearing interest rate.

that combine credit, labor and non-durable goods markets [Dell'Ariccia and Garibaldi, 2005; den Haan et al., 2003; Wasmer and Weil, 2004; Petrosky-Nadeau and Wasmer, 2013, 2015] but it is surprisingly novel for models of the housing market, in which access to credit plays a central role.

Characterization of the credit market via an aggregate matching function maintains the model tractable and is in line with several empirical findings. Dell'Ariccia and Garibaldi [2005] document that credit contractions are more volatile than credit expansions and that gross flows are much larger than net flows in the credit market. This evidence is consistent with a matching model in which banks need time to identify new profitable clients after a positive aggregate shock, but can recall credit without time delay after a negative aggregate shock. An efficiency increase of the credit market matching function can also explain the observed increase in average geographical distance between lenders and borrowers that occurred during the IT revolution [Petersen and Rajan, 2002].

Agents in the economy are risk-neutral and of four different types: households (h), investors (i) and their respective lenders (l_h and l_i).[19] Time is continuous with an infinite horizon. All agents discount the future with factor $r > 0$. The population of households is exogenously given and denoted by $\mathcal{H}$. Investors can enter freely the housing market and lenders can enter freely in the credit market. Their respective total number in equilibrium is endogenously determined by the model.

Developers can build new houses if existing properties are not sufficient to satisfy households and investors' demand. New dwellings stock is supplied at construction cost K. As in Gabrovski and Ortego-Marti [2019], I assume that new sellers can enter the housing market at this cost.[20] Given that all houses are identical, the value of a house on sale is determined by the free entry condition, regardless of whether it is a newly built house posted by a developer or an old house posted. Construction cost is an increasing function of new residential constructions e due to capacity constraints: $K = K(e)$ and $K'(e) \geq 0$. This corresponds to assuming a positive cost elasticity of supply and is a generalization of Gabrovski and Ortego-Marti [2019], which assume an infinite elasticity of supply with constant K. Vacant houses depreciate at a constant exogenous rate δ.

Houses are homogeneous, but they are heterogeneous in terms of wealth. A fraction σ_h (σ_i) of

[19] The model focuses on long-term buy-to-let investors rather than on short-term speculators (flippers). Empirically, buy-to-let investors appear to be mostly long-term investors, considering that the probability of reselling a buy-to-let property within the first six years is lower than for other dwellings [Bracke, 2021].

[20] Free entry of both buyers and sellers is a departure from standard search models of the labour market, in which the measure of sellers (the labor force) is exogenously given. A similar model leads mechanically to a downward sloping Beveridge curve, which fits well the labor market. However, Díaz and Jerez [2013] and Gabrovski and Ortego-Marti [2019] explain that the sign of the empirically estimated price elasticities of house vacancies, time to sell and sales indicate that the Beveridge curve is upward sloping in the housing market. Gabrovski and Ortego-Marti [2019] shows that a model with endogenous entry of both buyers and sellers can replicate well these features of the data. Developers do not play an important role in the model, other than supplying houses to the market when not enough houses become vacant.

households (investors) who search for a property do not need a mortgage to purchase it. Households own at most one property so they pay the standard ad-valorem transaction tax τ_h, whereas investors are buyers of multiple properties, so they pay a higher ad-valorem transaction tax which includes the surcharge $\tau_i > \tau_h$. Households earn income y. When they rent a house, they pay rental price R to investor-owners which is endogenously determined by the model. When they become owners, they stop paying the rent and they receive homogeneous housing utility ε_h. On the other hand, investors earn R when they own a house and have homogeneous housing utility ε_i (e.g. maintenance costs). Rental price R instantaneously clears the rental market.

6.1 Timing and meeting probabilities

Buyers of type $j \in \{h, i\}$ can either buy a house outright or using a mortgage. In the latter case, mortgage amounts are negotiated before prices. This replicates the common practice of mortgage 'agreements in principle' (AIP) in the UK. Buyers obtain information on the mortgage amount they can obtain from a bank before searching for a house and estate agents and sellers generally ask to see an AIP before agreeing to a sale [Lloyds Bank plc, 2022]. Agents face three stages:

- Stage 0: buyers and lenders randomly search. When they meet, they negotiate over the loan amount a_j in exchange for a flow mortgage repayment ρ_j for any given price p_j^L.
- Stage 1: buyers and sellers randomly search. When they meet, they negotiate the price p_j^L and buyers pay $p_j^L(1+\tau_j) - a_j$,
- Stage 2: owners receive housing utility ε_j and pay lenders ρ_j until a moving shock, which occurs at rate π_j.[21]

If they choose to buy a house outright, they face two stages:

- Stage 1: buyers and sellers randomly search. When they meet, they negotiate the price p_j and buyers pay $p_j(1+\tau_j)$.
- Stage 2: owners receive housing utility ε_j until a moving shock, which occurs at rate π_j.

To find a seller, household-buyers and investor-buyers compete in the same property market with tightness $\theta = \frac{h_1+h_1^L+i_1+i_1^L}{s_1}$. h_1, i_1, h_1^L, i_1^L and s_1 are the measures of household-buyers and investor-buyers with and without a mortgage agreement and the measure of sellers in stage 1,

[21] Using Land Registry data, I calculate an average home-ownership duration of 22.2 years for investors and 25.6 years for households (Section 8). This is quite similar to the median mortgage duration, which was 25 years in 2006 [FCA, 2019]. Since agents have linear utility of income and they discount utility at the same rate of lenders, mortgage duration is not relevant for their decisions.

respectively. Meeting probabilities are determined by a standard constant returns to scale matching function $M(h_1 + h_1^L + i_1 + i_1^L, s_1)$ which is increasing and concave in its arguments [Pissarides, 2000]. Accordingly, buyers find sellers with probability

$$\frac{M(h_1 + h_1^L + i_1 + i_1^L, s_1)}{h_1 + h_1^L + i_1 + i_1^L} = M(1, \theta^{-1}) = m(\theta) \tag{5}$$

Since search is random, sellers find a type-j buyer with probability $\frac{j_1}{h_1+h_1^L+i_1+i_1^L}\theta m(\theta)$, where $j \in \{h_1, h_1^L, i_1, i_1^L\}$. By properties of the matching function $m(\theta)$ and $\theta m(\theta)$ are respectively decreasing and increasing in θ.

If they choose to buy using a mortgage, household- and investor-buyers randomly search for a lender in different credit markets with tightness $\phi_h = \frac{h_0^L}{l_{h0}}$ and $\phi_i = \frac{i_0^L}{l_{i0}}$. h_0^L, i_0^L, l_{h0} and l_{i0} are the measures of household-buyers, investor-buyers and their respective lenders in stage 0. Meeting probabilities are determined by standard matching functions à la Pissarides [2000] $M_h(h_0^L, l_{h^L0})$ and $M_i(i_0^L, l_{i0})$. Accordingly, buyers find a lender with probabilities

$$\frac{M_j(j_0^L, l_{j0})}{j_0} = M(1, \phi_j^{-1}) = q_j(\phi_j), \quad j \in \{h, i\} \tag{6}$$

Lenders find a type-j buyer with probability $\phi_j q_j(\phi_j)$. By properties of the matching function $q_j(\phi_j)$ and $\phi_j q_j(\phi_j)$ are respectively decreasing and increasing in ϕ_j.

6.2 Agent values

Household-renters who are not sufficiently wealthy to buy a property outright choose whether to search for a lender. If they do, they pay search cost χ_h and find a lender at rate $q_h(\phi_h)$. They have value:

$$rH_0^L = y - R + \max\{-\chi_h + q_h(\phi_h)\max\{H_1^L - H_0^L, 0\}, 0\} \tag{7}$$

Once they have a mortgage agreement in principle, household-renters decide whether to search for a seller at cost c_h and they find one at rate $m(\theta)$. They have value:

$$rH_1^L = y - R + \max\{-c_h + m(\theta)\max\{H_2^L - [p_h^L(1+\tau_h) - a_h] - H_1^L, 0\}, 0\} \tag{8}$$

If they purchase a house they pay the after-tax price $p_h^L(1+\tau_h)$ net of the mortgage amount a_h. Once they own a house, households with a mortgage receive additional utility ε_h, pay mortgage repayment ρ_h until a moving shock which occurs at rate π_h. In that case they become renter-buyers and sellers at the same time with value $H_0^L + S_1$:

$$rH_2^L = y + \varepsilon_h - \rho_h + \pi_h[H_0^L + S_1 - H_2^L] \tag{9}$$

In equilibrium, households are indifferent between searching for a mortgage or not: $-\chi_h + q_h(\phi_h)\max\{H_1^L - H_0^L, 0\} = 0$

The values for investors who need a mortgage to buy a house are symmetric to the households', except for the fact that investors do not pay rent while searching for a house and they receive rental payment R when they own a property. Their values are:

$$rI_0^L = \max\{-\chi_i + q_i(\phi_i)\max\{I_1^L - I_0^L, 0\}, 0\} \tag{10}$$

$$rI_1^L = \max\{-c_i + m(\theta)\max\{I_2^L - [p_i^L(1+\tau_i) - a_i] - I_1^L, 0\}, 0\} \tag{11}$$

$$rI_2^L = R + \varepsilon_i - \rho_i + \pi_i[\max\{I_0^L, 0\} + S_1 - I_2^L] \tag{12}$$

In equilibrium, investors are indifferent between searching for a mortgage or not: $-\chi_i + q_i(\phi_i)\max\{I_1^L - I_0^L, 0\} = 0$

For household-renters that are sufficiently wealthy to buy a house outright, the choice is between searching for a seller, searching for a lender or not searching. Their value is:

$$rH_1 = y - R + \max\{-c_h + m(\theta)\max\{H_2 - p_h(1+\tau_h) - H_1, 0\}, -\chi_h + q_h(\phi_h)\max\{H_1^L - H_1, 0\}, 0\} \tag{13}$$

The value for a household-owner without a mortgage is simply:

$$rH_2 = y + \varepsilon_h + \pi_h[\max\{H_1, H_R\} + S_1 - H_2] \tag{14}$$

For investors that are sufficiently wealthy to buy a house outright, the values are symmetric:

$$rI_1 = \max\{-c_i + m(\theta)\max\{I_2 - p_i(1+\tau_i) - I_1, 0\}, -\chi_i + q_i(\phi_i)\max\{I_1^L - I_1, 0\}, 0\} \tag{15}$$

$$rI_2 = R + \varepsilon_i + \pi_h[\max\{I_1, 0\} + S_1 - I_2] \tag{16}$$

Notice that households and investors that are sufficiently wealthy to buy a house outright will always choose to do so in equilibrium (see Appendix Section B.4).

Lenders pay a screening cost χ_{Lj} until they find a type-*j* buyer, which occurs at rate $\phi_j q_j(\phi_j)$. Their value is:

$$rL_{j0} = -\chi_{Lj} + \phi_j q_j(\phi_j) \max\{L_{j1} - L_{j0}, 0\}, \quad j \in \{h, i\} \tag{17}$$

The value of a lender waiting for the type-*j* buyer to find a seller is:

$$rL_{j1} = m(\theta)[L_{j2} - a_j - L_{j1}], \quad j \in \{h, i\} \tag{18}$$

When the type-j buyer find a property to buy, the lender pays the loan amount a_j. A lender under a mortgage contract with a type-*j* buyer receive flow payments ρ_j until the moving shock:

$$rL_{j2} = +\rho_j + \pi_j[\max\{L_{j0}, 0\} - L_{j2}], \quad j \in \{h, i\} \tag{19}$$

Finally, household and investor sellers have an identical value. They pay search cost c_s, face depreciation δ and find a buyer with probability $\theta m(\theta)$. Since search is random, the probability to find a buyer of a particular type conditional on finding a buyer is equal to the type-share among buyers. Denote these type-share of buyers as $\tilde{j} = \frac{j}{h_1 + h_1^L + i_1 + i_1^L}$ for $j \in \{h_1, h_1^L, i_1, i_1^L\}$. They are derived in section B.3 as functions of housing market tightness θ and new constructions e. Then, the value of sellers is:

$$\begin{aligned} rS_1 = -c_s - \delta S_1 + \theta m(\theta) \Big[& \tilde{h}_1^L(e,\theta) \max\{p_h^L - S_1, 0\} + \tilde{h}_1(e,\theta) \max\{p_h - S_1, 0\} \\ & + \tilde{i}_1^L(e,\theta) \max\{p_i^L - S_1, 0\} + \tilde{i}_1(e,\theta) \max\{p_i - S_1, 0\} \Big] \end{aligned} \tag{20}$$

In equilibrium, there is free entry of lenders ($L_{h1} = L_{i1} = 0$) and sellers enter at construction cost $K(e)$: $S_1 = K(e)$. To summarize, the equilibrium conditions are:

$$\begin{aligned} S_1 = K(e), \quad H_1^L - H_0^L = \frac{\chi_h}{q_h(\phi_h)}, \quad I_1^L - I_0^L = \frac{\chi_i}{q_i(\phi_i)}, \\ L_{h1} - L_{h0} = \frac{\chi_{lh}}{\phi_i q_h(\phi_h)}, \quad L_{i1} - L_{i0} = \frac{\chi_{li}}{\phi_i q_i(\phi_i)} \end{aligned} \tag{21}$$

6.3 Prices and mortgage negotiations

There are two types of negotiations in the economy: the mortgage amount negotiated between buyers and lenders and the property transaction price bargained between buyers and sellers. For buyer-borrowers, these contracts are negotiated sequentially. Buyers and sellers take as given the loan amount which was agreed before they met. Accordingly, lenders and buyers know that the result of their negotiation will affect the bargaining over the property price.

To solve this sequential problem, we proceed by backwards induction. In stage 1, buyers and sellers bargain the price, given the mortgage amount negotiated in stage 0. They maximize the surplus of the property transaction according to the following Nash bargaining rules:[22]

$$\begin{aligned} &\max_{p_h^L}[p_h^L - S_1]^{\beta_h}[H_2 - p_h^L(1+\tau_h) + a_h - H_1]^{1-\beta_h}, \\ &\max_{p_i^L}[p_i^L - S_1]^{\beta_i}[I_2 - p_i^L(1+\tau_i) + a_i - I_1]^{1-\beta_i} \end{aligned} \tag{22}$$

where β_j is the seller's bargaining power when meeting a type-j buyer ($j \in \{h, i\}$). The mortgage amounts a_j are negotiated when buyers and lenders meet, taking into account the impact they will have on property prices negotiated in the future.[23] Lenders and buyers maximize the surplus of their relationship according to the following Nash bargaining rules:

$$\max_{a_h}[L_{h1} - L_{h0}]^{\psi_h}[H_1 - H_0]^{1-\psi_h}, \quad \max_{a_i}[L_{i1} - L_{i0}]^{\psi_i}[I_1 - I_0]^{1-\psi_i} \tag{23}$$

where ψ_j is the seller's bargaining power when meeting a type-j buyer ($j \in \{h, i\}$).

Buyers that are not borrowers simply negotiate the price with sellers to maximize the transaction surplus:

$$\max_{p_h}[p_h - S_1]^{\beta_h}[H_2 - p_h(1+\tau_h) - H_1]^{1-\beta_h}, \quad \max_{p_i}[p_i - S_1]^{\beta_i}[I_2 - p_i(1+\tau_i) - I_1]^{1-\beta_i} \tag{24}$$

Solving these surplus maximization problems and plugging the equilibrium conditions yield equilibrium equations for prices and loan amounts (see Appendix Section B.1).

The equilibrium values for loan amounts a_j satisfy:

$$\frac{\rho_j}{r+\pi_j} = a_j + \psi_j\left(\frac{R+\varepsilon_j+\pi_j K(e)}{r+\pi_j} - (1+\tau_j)K(e) - \frac{c_j}{(1-\beta_j)m(\theta)} + \frac{\beta_j \chi_j}{(1-\beta_j)q_j(\phi_j)}\right), \quad j \in \{h, i\} \tag{25}$$

The present discounted value of mortgage repayments is equal to the loan amount plus the lender's share of the house transaction surplus net of buyer's search cost. In equilibrium, non-borrowers

[22] As shown by Rubinstein [1982], sharing the surplus according to the agents' bargaining power is the subgame perfect equilibrium outcome of an infinite-horizon, alternating-offers bargaining game in which every agent has a fixed discount factor. A player's bargaining power monotonically increases with their discount factor.

[23] I assume buyers and lenders negotiate over loan amounts a_j taking mortgage repayment ρ_j as given. For instance, mortgage repayment could be a fixed fraction of the borrower's income: $\rho_j = \lambda y$ where $\lambda \in (0, 1)$. The model is isomorphic if buyers and lenders negotiate over mortgage repayments and take the loan amount as given.

pay prices:

$$p_j = K(e) + \frac{\beta_j}{1+\tau_j}\left[\frac{\varepsilon_j + R - rK(e) - (r+\pi_j)\tau_j K(e) + c_j}{r+\pi_j+(1-\beta_j)m(\theta)}\right], \quad j \in \{h,i\} \tag{26}$$

In equilibrium, borrowers pay prices:

$$\begin{aligned} p_j^L =& K(e) + \frac{\beta_j}{(1+\tau_j)}\left[\frac{\varepsilon_j + R - rK(e) - (r+\pi_j)\tau_j K(e)}{r+\pi_j} - \frac{\chi_j}{q_j(\phi_j)} - \frac{\rho_j}{r+\pi_j} + a_j\right], \quad j \in \{h,i\} \\ =& K(e) + \frac{\beta_j}{(1+\tau_j)}\left[(1-\psi_j)\left(\frac{\varepsilon_j + R - rK(e) - (r+\pi_j)\tau_j K(e)}{r+\pi_j}\right) - \frac{[1-\beta_j(1-\psi_j)]\chi_j}{(1-\beta_j)q_j(\phi_j)} + \frac{\psi_j c_j}{(1-\beta_j)m(\theta)}\right] \end{aligned} \tag{27}$$

Prices are simply equal to construction cost plus the seller's share of the transaction surplus. Prices for buyers with a mortgage decrease with mortgage repayments (interest rates) and increase with the loan amount borrowers are able to obtain. Intuitively, the average price decreases with credit frictions $\frac{\chi_j}{q_j(\phi_j)}$ and increases with rental price R, construction cost $K(e)$ and housing market tightness θ *ceteris paribus*. However, one has to solve for the equilibrium values of the endogenous variables $(\phi_i, \phi_h, \theta, R, e)$ to account for general equilibrium effects.

6.4 The financial accelerator

To understand how a reduction in credit market frictions can affect the housing market, we can analyze the relationship between credit frictions and housing market tightness. Using the equilibrium and forward expressions for the values of borrowers and lenders (see Appendix Section B.2), we obtain the following equations:

$$\frac{\chi_j}{q_j(\phi_j)} = \frac{(1-\psi_j)}{r+m(\theta)[1-\beta_j(1-\psi_j)]}\left\{-c_j + m(\theta)(1-\beta_j)\left[\frac{\varepsilon_j + R - rK(e) - (r+\pi_j)\tau_j K(e)}{r+\pi_j}\right]\right\} \tag{BE_j}$$

$$\frac{\chi_{lj}}{\phi_j q_j(\phi_j)} = \frac{\psi_j/(1-\beta_j)}{r+m(\theta)[1-\beta_j(1-\psi_j)]}\left\{-c_j + m(\theta)(1-\beta_j)\left[\frac{\varepsilon_j + R - rK(e) - (r+\pi_j)\tau_j K(e)}{r+\pi_j}\right]\right\} \tag{LE_j}$$

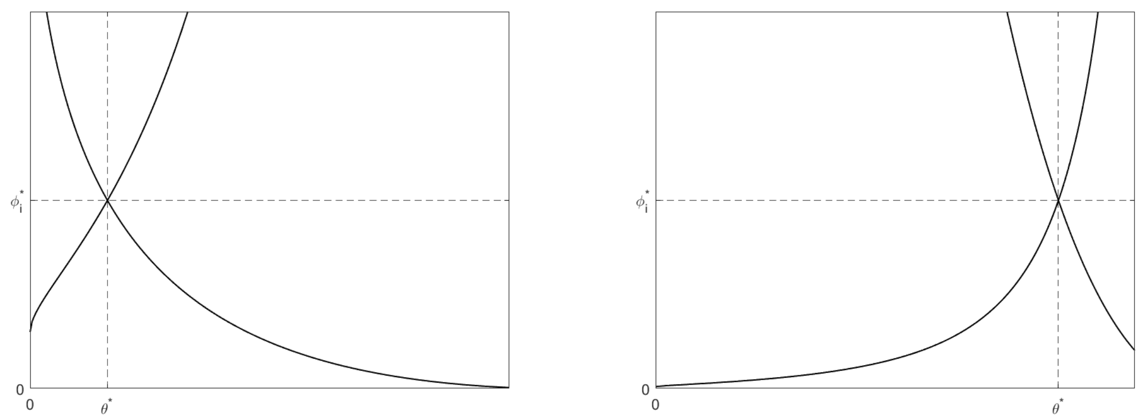
For given rental price R and construction cost $K(e)$, borrowers' entry equation (BE_j) defines a downward sloping iso-value curve in the (θ, ϕ_j) plane. If the expected cost of entry for a borrower is lower because the credit market is less tight, then the expected value of entering the property market can go to zero only if housing market tightness (i.e. expected duration of house search) is higher.

For given rental price R and construction cost $K(e)$, lenders' entry equation (LE_j) defines an upward-sloping iso-value curve in the (θ, ϕ_j) plane with a vertical asymptote at $\bar{\theta}$. If the expected cost of entry for a lender is higher because the credit market is less tight, then zero profits can only be achieved by having lower housing market tightness.

In the model a reduction in credit frictions corresponds to an increase in credit matching efficiency: an increase in the probability a buyers finds a lender $q_j(\phi_j)$) for any value of credit market tightness ϕ_j. These two equations show that a reduction in credit friction unambiguously increases housing market tightness. In the limit case in which credit frictions disappear ($q_j(\phi_j) \to \infty$), housing market tightness is maximized at value $\bar{\theta}$.

Borrowers and lenders' entry curves are represented in Figure 9. As we can see, an increase in credit market efficiency leaves credit market tightness unchanged but increases housing market tightness, for a given rental price R and construction cost $K(e)$.

Figure 9: The effect of a reduction in credit frictions on housing market tightness



(a) Low credit matching efficiency

(b) High credit matching efficiency

As [Wasmer and Weil, 2004] show for the labor market, credit market frictions can also amplify and propagate shocks to the housing market, acting in the form of a *financial accelerator*. A reduction in credit frictions increases the number of lenders, which incentivizes borrowers' entry, further encouraging lenders' entry and so on. Shocks to the credit sector result in an amplified effect on housing market tightness, which can in turn have a strong impact on housing prices. Differently from the labor market, shocks to the credit sector will have an impact on the rental market as well (the rental price R) which must be taken into account when analyzing how credit market frictions affect housing market tightness.

6.5 A recursive equilibrium

To solve the model, we need to find four endogenous variables: the credit market tightness for households ϕ_h, the credit market tightness for investors ϕ_i, the housing market tightness θ and the measure of new constructions e. Given these variables, we can find property prices using Equations (26)-(27) and the rental price using Equation (BE_j). In addition, we can find the equilibrium dwellings stock $D = \mathcal{H} + \frac{e}{\delta}$ and the stock all of agents in steady state using the stocks and flows equations presented in Appendix Section A and B.3.

Solving the surplus maximization problems in (23) and using the equilibrium conditions (21), we obtain equilibrium credit market tightness ϕ_j in each market:

$$\phi_j = \frac{(1-\beta_j)(1-\psi_j)\chi_{lj}}{\psi_j \chi_j}, \quad j \in \{h, i\} \tag{28}$$

As in [Wasmer and Weil, 2004], credit market tightness is constant in equilibrium and depends only on bargaining powers and search costs. The higher the bargaining powers of buyers in the credit and in the property market and the lower their credit search costs, the higher credit market tightness. The lower the bargaining power of lenders and the higher their credit search costs, the higher credit market tightness.

To find θ and e given ϕ_h and ϕ_i, first we can equalize the rental price in (BE_h) and (BE_i):

$$\begin{aligned}\frac{r+\pi_i}{m(\theta)(1-\beta_i)}\left\{\frac{\chi_i\{r+m(\theta)[1-\beta_i(1-\psi_i)]\}}{q_i(\phi_i)(1-\psi_i)}+c_i\right\}-\varepsilon_i+rK(e)+(r+\pi_i)\tau_i K(e) = R = \\ \frac{r+\pi_h}{m(\theta)(1-\beta_h)}\left\{\frac{\chi_h\{r+m(\theta)[1-\beta_h(1-\psi_h)]\}}{q_h(\phi_h)(1-\psi_h)}+c_h\right\}-\varepsilon_h+rK(e)+(r+\pi_h)\tau_h K(e)\end{aligned} \tag{29}$$

This equation represents the market clearing of the rental market. For a given housing market tightness, the rental price increases when investors face higher frictions in the credit market because there is lower supply in the rental market. For a given housing market tightness, the rental price increases when households face higher frictions in the credit market because there is higher demand in the rental market (and lower demand in the property market).

Secondly, to close the model we use sellers' entry Equation (20):

$$\begin{aligned}rK(e) = -c_s - \delta K(e) + \theta m(\theta)\Big[&\tilde{h}_1^L(e,\theta)[p_h^L - K(e)] + \tilde{h}_1(e,\theta)[p_h - K(e)] \\ &+ \tilde{i}_1^L(e,\theta)[p_i^L - K(e)] + \tilde{i}_1(e,\theta)[p_i - K(e)]\Big]\end{aligned} \tag{30}$$

where prices are given by Equations (26)-(27) and the shares of buyers are given by Equations (80)-(83) derived in Appendix Section B.3.

One can obtain e as a function of θ from Equation (30) and then plug it in Equation (29). The solution of the model depends on the functional form of $K(e)$. Under infinite elasticity of supply, the construction cost $K(e)$ is independent of the number of constructions e and the stationary equilibrium of this model is a recursive equilibrium, in which we can solve for θ using (29) and then we can plug it in (30) to solve for e.

7 Comparative statics

7.1 The short run

In this section, I use the model to show how equilibrium effects can rationalize the empirical findings of Section 5:

- A decrease in the number of transactions;
- An increase in time-to-sell;
- A reduction in average rental prices;
- A decrease in property prices for investors and, to a lesser extent, for households;
- An insignificant decrease in the number of constructions.

The effects analyzed in most of the post-surcharge period (2016-2019) can be approximately interpreted as short- and medium-run effects, considering that the average construction period is 2.5 years for sites between 100 and 499 units and 5 years for sites over 1,000 units in England [Swan, 2016]. In the short run, we can assume the dwellings stock D is fixed and, accordingly, the construction cost K is also fixed.

First of all, using the implicit function theorem on Equation (29), we see that the probability of finding a buyer increases with the introduction of a surcharge on investors ($\frac{dm(\theta)}{d\tau_i} > 0$) if

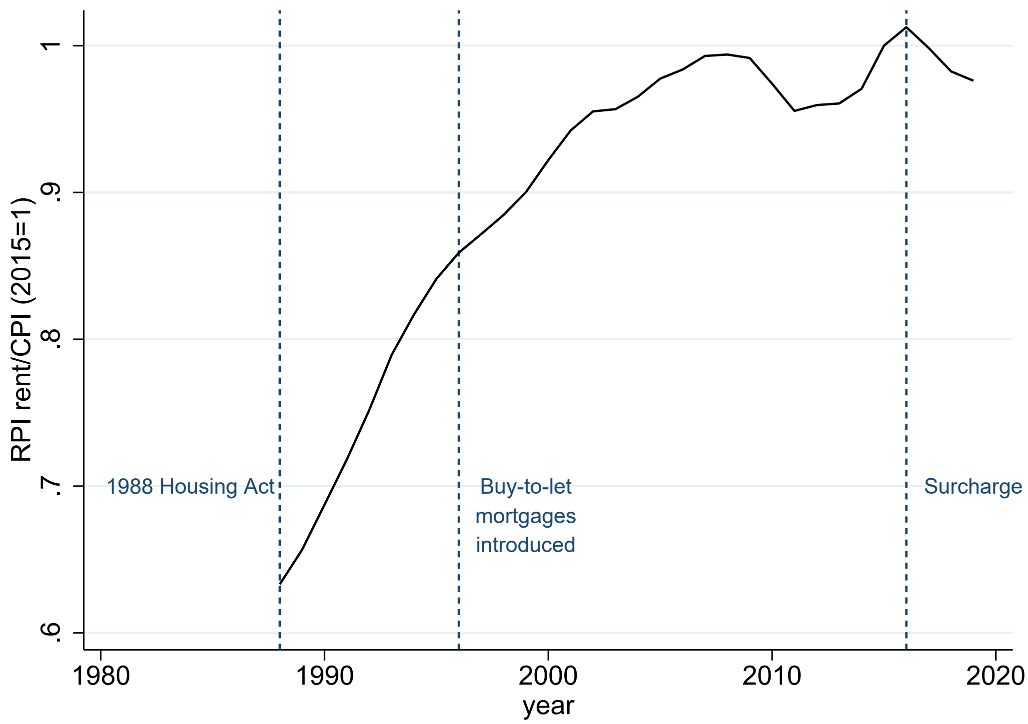
$$\begin{aligned} &-\varepsilon_i + (r+\pi_i)K\tau_i + \frac{(r+\pi_i)[1-\beta_i(1-\psi_i)]}{(1-\beta_i)(1-\psi_i)}\frac{\chi_i}{q_i(\phi_i)} \\ &< -\varepsilon_h + (r+\pi_h)K\tau_h + \frac{(r+\pi_h)[1-\beta_h(1-\psi_h)]}{(1-\beta_h)(1-\psi_h)}\frac{\chi_h}{q_i(\phi_h)} \end{aligned} \tag{31}$$

Therefore, if credit search frictions for households are substantially larger than credit search frictions for investors at the moment of the tax change, we would expect the tax to increase buyer's probability to find a property to buy and to decrease seller's probability to find a buyer, i.e. to reduce housing market tightness. In Section 8, I estimate that the credit market frictions for households are substantially larger than the credit market frictions for investors in 2015 and condition (31) holds. Accordingly, we should observe an increase in time to sell $\frac{1}{\theta m(\theta)}$, which is what I find in the reduced-form analysis of Section 5.

As population $\mathcal{H}$ in the model is fixed, the number of sellers $s_1 = D - \mathcal{H}$ is also fixed in the short run. Since housing market tightness decreases with the surcharge on investors and the number of sellers is fixed, in the short-run we expect a decrease in the number of buyers (in particular investor-buyers) and, accordingly, a decrease in the number of matches: $\frac{dM(h_1+h_1^L+i_1+i_1^L,s_1)}{d\tau_i} < 0$. This corresponds to the empirical finding that there is a significant reduction in the number of transactions (matches) due to the surcharge on investors. The tax reduces the number of buyers relative to the number of sellers and this makes it harder for sellers to sell their property.

The increase in the probability of finding a property to buy results in a reduction in rental prices. From the second equality in (29), it is clear that $\frac{dR}{d\tau_i} = -\frac{(r+\pi_h)r\chi_h}{(1-\beta_h)q_h(\phi_h)(1-\psi_h)m(\theta)^2}\frac{dm(\theta)}{d\tau_i} < 0$ when $\frac{dm(\theta)}{d\tau_i} > 0$. This is due to a reduction in rental demand as households find properties to buy more easily and an increase in rental supply as investors find properties to buy-to-let more easily. Even though the identification strategy does not allow to analyze the impact on rental prices, we see in Figure 10 that the average deflated rental price in England and Wales peaks and starts to decrease exactly when the surcharge on investors is introduced.

Figure 10: Rental price over time



When the housing market decreases, the short-run impact that a surcharge on investors has on property prices is unambiguously negative *for each type of buyer*. To see this, we can use the implicit function theorem on price equations (26)-(27) to obtain:

$$\frac{dp_h}{d\tau_i} = \frac{\beta_h \frac{dR}{d\tau_i} - [(p_h - K)(1-\beta_h)(1+\tau_h)]\frac{dm(\theta)}{\tau_i}}{[r+\pi_h+m(\theta)(1-\beta_h)](1+\tau_h)} < 0 \tag{32}$$

$$\frac{dp_h^L}{d\tau_i} = \frac{\frac{\beta_h(1-\psi_h)}{r+\pi_h}\frac{dR}{d\tau_i} - \frac{\beta_h\psi_h}{(1-\beta_h)}[\frac{1}{m(\theta)^2}]\frac{dm(\theta)}{\tau_i}}{(1+\tau_h)} < 0 \tag{33}$$

$$\begin{aligned}\frac{dp_i}{d\tau_i} =& \frac{\beta_i \frac{dR}{d\tau_i} - [(p_i - K)(1-\beta_i)(1+\tau_i)]\frac{dm(\theta)}{\tau_i}}{[r+\pi_i+m(\theta)(1-\beta_i)](1+\tau_i)} \\ &- \frac{\{p_i[r+\pi_i+m(\theta)(1-\beta_i)] - (1-\beta_i)K[r+\pi_i+m(\theta)]\}}{[r+\pi_i+m(\theta)(1-\beta_i)](1+\tau_i)} < 0\end{aligned} \tag{34}$$

$$\frac{dp_i^L}{d\tau_i} = \frac{\frac{\beta_i(1-\psi_i)}{r+\pi_i}\frac{dR}{d\tau_i} - \frac{\beta_i\psi_i}{(1-\beta_i)}\left[\frac{1}{m(\theta)^2}\right]\frac{dm(\theta)}{\tau_i}}{(1+\tau_i)} - \frac{\{p_i^L - K[1-\beta_i(1-\psi_i)]\}}{(1+\tau_i)} < 0 \tag{35}$$

The surcharge for multiple-property investors has three different effects on prices. A *direct tax incidence effect* which has an impact only on properties purchased by investors: the last term on the right-hand side of (34) and (35).[24] In addition, there are *two equilibrium effects* through which the surcharge on investors reduces prices for all buyers:

1. an increase in the probability to find a property to buy ($\frac{dm(\theta)}{d\tau_i}$) which favors buyers over sellers;

2. a decrease in rental price ($\frac{dR}{d\tau_i}$) which pushes down demand for buying properties by households (because renting a house is now cheaper) and by investors (because letting a house is now less profitable).

Thanks to these two equilibrium effects, there is a price decrease even for those transactions that are not directly affected by the surcharge (p_h and p_h^L), namely the transactions for households that want to move to a new home or to buy their first property.

7.2 The long run

In the long run, the dwellings stock adjusts to reach a new equilibrium. In particular, note that the equilibrium equation for dwellings (30) can be rearranged as:

$$K(e) = \frac{-c_s + \theta m(\theta)}{(r+\delta) + \theta m(\theta)}\bar{p} \tag{36}$$

where $\bar{p}$ is the average price across all types of buyers. Since the surcharge on investors reduces all prices ($\frac{d\bar{p}}{d\tau_i} < 0$) and market tightness ($\frac{d\theta m(\theta)}{d\tau_i} < 0$), the construction cost must decrease for the housing market to reach a new equilibrium ($\frac{dK(e)}{d\tau_i} < 0$). As construction cost is increasing in constructions e, the equilibrium number of construction (and total dwellings stock) should decrease. Indeed, the number of new constructions appears to decrease due to the surchage especially at the end of the analysed period (Figure 5), even though the total effect is insignificant (Table C2). The adjustment of the dwellings stock should be smaller, the lower the elasticity of supply. Malpezzi

[24] This term is unambiguously negative as each price must be larger than the construction cost K in an equilibrium in which each type of buyer is active, otherwise their respective transaction surplus would be negative.

and Maclennan [2001] estimate a low long-run price elasticity of supply of new residential construction in the UK (between 0 and 1), explaining the lack of a strong supply response to the surcharge.

Ultimately, the decrease in construction cost will directly amplify the negative effect on prices but also have a feedback effect on housing market tightness, which will lead to a new equilibrium. In Section 8, I calibrate the model to the pre-surcharge period and simulate the new equilibrium after the surcharge on investors is introduced. The comparison between the pre- and post-surcharge equilibrium shows that the model can qualitatively replicate all the main effects estimated in Section 5 and allows to perform a welfare analysis of the surcharge.

8 Identification and calibration

Assuming a standard Cobb-Douglas housing matching function $\theta m(\theta) = \nu\theta^{1-\gamma}$. Also assume the construction cost has the functional form $K(e) = a - b/e$ with $a, b > 0$. Note that this functional form satisfies the property $K'(e) > 0$ and simplifies the solution of the model as sellers' entry Equation (30) becomes linear in new constructions e. The parameters to calibrate in the model are: $\beta_h, \beta_i, c_h, c_i, c_s, \chi_h, \chi_i, \delta, \varepsilon_h, \varepsilon_i, \gamma, \nu, \pi_h, \pi_i, \psi_h, \psi_i, r, a, b, \sigma_h, \sigma_i, \mathcal{H}$.[25]

To calibrate some parameters I use previous estimates, and to calibrate others I directly match them to analogue moments or quantities in the data (Table 6). I determine the rest of the parameters plugging data analogues into model equations at the steady state. To calibrate the model, I target data for 2015, the year before the introduction of the surcharge.

The demolition rate δ is calculated by dividing the number of demolitions over the number of vacant houses in England and taking the average from 2006 to 2019 [Ministry of Housing, 2019]. This yields a demolition rate of 0.019. To compute the moving rate for owner-occupiers and investors, I have merged the Land Registry Price-Paid data with the Energy Performance Certificate data, which contains an indicator on whether the property is owner-occupied or privately rented. Given the latter dataset starts in 2008, I focus on the period 2008-2019 and compute the hazard rate for properties that already existed in 2008. The total number of properties owned by an investors (rented) and households (owner-occupied) that existed in 2008 in England is observed. Since the hazard rate is assumed to be constant, the hazard rate for a single property is simply equal to the number of events (number of transactions in 2008-2019) divided by the time lapse (12 years). Since virtually all standard transactions should be lodged in the Land Registry, I assume that properties

[25] We can also assume Cobb-Douglas matching functions for the credit market: $M_h(h_1, l_{h1}) = \nu_h l_{h1}^{\gamma_h} h_1^{1-\gamma_h}$ and $M_i(i_1, l_{i1}) = \nu_i l_{i1}^{\gamma_i} i_1^{1-\gamma_i}$. The parameters $\chi_{Lh}, \chi_{Li}, \gamma_h, \gamma_i, \nu_h, \nu_i$ are not necessary to obtain the equilibrium variables of interest in the model. They can be used to estimate the measure of lenders and the credit market tightness, which are not the focus of this paper.

that do not appear in this dataset had zero events in the period of interest.[26] Then, taking the average of all individual hazard rates, I obtain an average hazard rate for households of $\pi_h = 0.04$ and an average hazard rate for investors $\pi_i = 0.05$. The implied average duration of stay is 20 years for investors and 25 years for households.

From model equations, we can estimate the probability a seller finds a buyer $\theta m(\theta)$:

$$\theta m(\theta) = \frac{\mathcal{H}}{D - \mathcal{H}} \left[\pi_h \left(\frac{h_2 + h_2^L}{\mathcal{H}} \right) + \pi_i \left(\frac{i_2 + i_2^L}{\mathcal{H}} \right) \right] \tag{37}$$

where we can observe the number of vacant homes $D - \mathcal{H}$, the number of occupied homes $\mathcal{H}$, the share of owner-occupied properties $\frac{h_2+h_2^L}{\mathcal{H}}$, and the share of privately rented properties $\frac{i_2+i_2^L}{\mathcal{H}}$ in 2015 [EHCS, 2004; Ministry of Housing, 2019]. Using this method, I obtain an estimate of $\theta m(\theta) = 1.62$ or, equivalently, an average time to sell of around seven months. This is reassuringly close to the median of six months between the listing date and the sale date observed for properties listed on Zoopla in the period 2012-2019 [Consumer Data Research Centre, 2020a]. In addition, I target a time-to-buy of one year ($m(\theta) = 1$) [Burridge, 2022] and the estimated 4% increase in the time-to-sell caused by the tax surcharge on investors.[27] I can then obtain θ and estimate the parameters ν and γ.

To identify σ_h and σ_i, I target the number of households' mortgages h_2^L, the number of buy-to-let mortgages i_2^L as well as the number of total properties occupied by households $h_2 + h_2^L$ and rented $i_2 + i_2^L$ [Ministry of Housing, 2022b; Council of Mortgage Lenders, 2022]. Then, using model equations we can estimate:

$$\sigma_j = \frac{j_2[1 + \frac{m(\theta)}{\pi_j}]}{j_2^L[1 + \frac{m(\theta)}{\pi_j}\frac{m(\theta)}{j(\phi_j)}] + j_2[1 + \frac{m(\theta)}{\pi_j}]}, \quad j \in \{h, i\} \tag{38}$$

.

This yields an estimate for the share of households that search for a property without a mortgage of $\sigma_h = 0.35$ and the share of investors that search for a property without a mortgage of $\sigma_i = 0.62$.

I calibrate the ratio of the search cost for sellers to the average price to be 0.01 in order to account for a 1% maintenance cost [BCIS, 2022]. In absence of data, the estimated search cost for investors c_i is assumed to be equal to the cost for sellers. The estimated search cost for households c_h is based on the opportunity cost of the time spent searching a property, following the approach by Ngai and Sheedy [2020]. I assume one property viewing entails the loss of half a day of

[26] The Price Paid Data excludes sales that have not been lodged with HM Land Registry, sales that were not for value transfers, conveyances, assignments or leases at a premium with nominal rent, Vesting Deeds Transmissions or Assents of more than one property

[27] This is the average of the estimates across the different regression specifications in Table 3 after adjusting for the local authority share of rented properties.

average annual income Y in 2015, where data on annual income are from the Annual Survey for Hours and Earnings [ONS]. The value of c_h and c_i up the cost of making the expected number of viewings. According to leading estate and letting agents [LSL property services plc, 2022], the average number of viewings before buying is $V_b = 9$. To buy a property the average cost is $c_h = V_b \frac{Y}{2 \cdot 365}$. As the time to buy a property is $1/m(\theta)$, the expected annual search cost for a buyer is set to $m(\theta) V_b \frac{Y}{2 \cdot 365}$, which corresponds to 1.2% of annual income.

Construction cost for each year t is identified by using sellers' entry equation

$$K = \left(\frac{\theta m(\theta) - \frac{c_s}{\bar{p}}}{r + \delta + \theta m(\theta)} \right) \bar{p} \tag{39}$$

where $\bar{p}$ is the observed median price in 2015. Targeting an elasticity of supply of $\eta = 0.1$ [Malpezzi and Maclennan, 2001], I can obtain estimates for $a = K(1 + \frac{1}{\eta})$ and $b = \frac{\delta(D - \mathcal{H})K}{\eta}$.

I assume a symmetric bargaining power both in the credit market $\psi_h = \psi_i = 0.5$, as in Petrosky-Nadeau and Wasmer [2013], and in the housing market $\beta_h = \beta_i = 0.5$, as in Ngai and Sheedy [2020]. As it takes between two and six weeks to obtain a mortgage (Barclays plc, 2021), I target an average mortgage-search duration of one month: $\frac{1}{q_h(\phi_h)} = \frac{1}{q_i(\phi_i)} = \frac{1}{12}$.

To estimate buyers' expected credit search costs, I use buyers' entry (BE_j) and price equations (26)-(27) which yield:

$$\frac{\chi_j}{q_j(\phi_j)} = \frac{(1 + \tau_j)(\bar{p}_j - K) m(\theta) \frac{(1-\beta_j)}{\beta_j} - c_j}{\left(\frac{j_1}{j^L + j_1} \right) \frac{(r+\pi_j)\{r + m(\theta)[1 - \beta_j(1-\psi_j)]\}}{[r + \pi_j + (1-\beta_j) m(\theta)](1-\psi_j)} + \left(1 - \frac{j_1^L}{j^L + j_1} \right) r}, \quad j \in \{h, i\} \tag{40}$$

where $\bar{p}_j$ is the observed median price paid by type-j buyer, and $\frac{j_1}{j^L + j_1}$ is the share of type-j buyer that buys properties without a mortgage.[28]

Finally, rearranging (BE_j) we obtain the housing utility for households and investors:

$$\varepsilon_j = -R + rK(e) + (r + \pi_j)\tau_j K(e) + \frac{r + \pi_j}{m(\theta)(1 - \beta_j)} \left(\frac{\frac{\chi_j}{q_j(\phi_j)} \{r + m(\theta)[1 - \beta_j(1 - \psi_j)]\}}{(1 - \psi_j)} + c_j \right), \quad j \in \{h, i\} \tag{41}$$

I find that households gain an intrinsic utility of $\pounds 5,277$ from owning a property for a year, whereas investors lose $\pounds 2,180$ per year from owning a property (e.g. maintenance costs, agency fees, income tax) which is more than compensated by the rental price of $\pounds 9,456$ they receive.

[28] Note that using the observed values for h_2, h_2^L, i_2 and i_2^L we can estimate h_1, h_1^L, i_1 and i_1^L from Equations (52) and (53) as $j_1 = \frac{\pi_j j_2}{m(\theta)}$ and $j_1^L = \frac{\pi_j j_2^L}{m(\theta)}$ for $j \in \{h, i\}$.

Table 6: Calibration

Parameter	Identification	Dataset/estimate	Value
Depreciation rate δ	Target percentage of UK vacant stock that in 2015.	Author's estimates using Ministry of Housing [2022b]	$\delta = 0.019$
Number of non-vacant privately owned dwellings $\mathcal{H}$	Target non-vacant privately owned dwellings in 2015.	Ministry of Housing [2022b] and EHCS [2004]	$\mathcal{H} = 18.96m$
Moving rate for households π_h and investors π_i	Average ratio between number of transactions and years observed across owner-occupiers' and investors' properties in 2008-2019.	Author's estimates using HM Land Registry [2019] and Department for Levelling Up, Housing and Communities [2022a]	$\pi_h = 0.04$, $\pi_i = 0.05$
Sellers'and investors' search cost c_s, c_i	Target maintenance cost as a percentage of price.	Author's estimates using BCIS [2022] and HM Land Registry [2019]	$c_s = c_i = 2049.5$
Households' search cost c_h	Target house visits before buying and median income.	Author's estimates using [LSL property services plc, 2022; ONS]	$c_h = 340.5$
Parameters of the construction cost function a, b	Previous estimate of elasticity of supply	Author's estimates using Malpezzi and Maclennan [2001]	$a = 20.2m$, $b = 0.19m$
Lenders' bargaining power with households ψ_h and investors ψ_i.	Previous calibration	Petrosky-Nadeau and Wasmer [2013]	$\psi_h = \psi_i = 0.5$
Housing matching function elasticity γ and efficiency ν	Model equations. Target vacant and occupied homes, shares of owner-occupied and rented properties in 2015. Target time to buy and post-surcharge 4% increase in time-to-sell.	Author's estimates using Burridge [2022], Ministry of Housing [2022b]	$\gamma = 0.96$, $\nu = 1.59$
Sellers' bargaining power with households β_h and investors β_i.	Previous calibration	Ngai and Sheedy [2020]	$\beta_h = \beta_i = 0.5$
Shares of searchers without a mortgage σ_h, σ_i	Model equations. Target households' and investors' mortgages, owner-occupied and rented properties.	Author's estimates using Ministry of Housing [2022b]; Council of Mortgage Lenders [2022]	$\sigma_h = 0.35$, $\sigma_i = 0.62$
Discount rate r	Target average 1-month Gilt repo interest rate in 2015	Bank of England [2018]	$r = 0.01$
Investors' expected credit search costs $\frac{\chi_i}{q_i(\phi_i)}$	Model equations. Target median price paid by investors, rental price, number of investors' mortgages and rented properties in 2015.	Author's estimates.	$\frac{\chi_i}{q_i(\phi_i)} = 27,075$
Households' expected credit search costs $\frac{\chi_h}{q_h(\phi_h)}$	Model equations. Target median price paid by households, rental price, households' mortgages and properties in 2015.	Author's estimates	$\frac{\chi_h}{q_h(\phi_h)} = 83,042$
Households' house utility ε_h	Model equations. Target median rental price in 2015.	Author's estimates	$\varepsilon_h = 5,277$
Investors' house utility ε_i	Model equations. Target median rental price in 2015.	Author's estimates	$\varepsilon_i = -2,180$

8.1 Model validation

9 Welfare analysis

The flow value of steady-state utility net of costs averaged across all households, investors and lenders is:

$$\begin{aligned} rW =& \mathcal{H}y - h_0^L\chi_h - h_1^L c_h + h_2^L\varepsilon_h - h_1 c_h + h_2\varepsilon_h - i_0^L\chi_i - i_1^L c_i + i_2^L\varepsilon_i - i_1 c_i + i_2\varepsilon_i \\ & - l_{h0}\chi_{lh} - l_{i0}\chi_{li} - sc_s - eK \end{aligned} \tag{42}$$

I do not subtract stamp-duty taxes from welfare as I assume the government redistributes all tax revenues to the agents in the economy.

10 Conclusions

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Appendix A Stocks and flows

Let j_n be the number of type $j \in \{h, i\}$ agents at stage $n \in \{1, 2\}$ without need of a mortgage to buy a property. Let h_0 be households who rent, but do not search for a mortgage or for a property to buy. Let j_n^L be the number of type $j \in \{h, i\}$ agents at stage $n \in \{0, 1, 2\}$ with need of a mortgage to buy a property. Let l_{jn} be the number of lenders to type $j \in \{h, i\}$ agents at stage $n \in \{0, 1, 2\}$.

Housing market tightness is:

$$\theta = \frac{h_1 + h_1^L + i_1 + i_1^L}{s_1} \tag{43}$$

Credit market tightnesses for households and investors are:

$$\phi_h = \frac{h_0^L}{l_{h0}}, \quad \phi_i = \frac{i_0^L}{l_{i0}} \tag{44}$$

The existing dwellings stock in steady state is:

$$D = s_1 + h_2^L + h_2 + i_2^L + i_2 \tag{45}$$

The measures of households is fixed at:

$$\mathcal{H} = h_0 + h_1 + h_2 + h_0^L + h_1^L + h_2^L \tag{46}$$

A fraction σ_h (σ_i) of households (investors) that search does not need a mortgage:

$$h_1 + h_2 = \sigma_h(h_1 + h_2 + h_0^L + h_1^L + h_2^L), \quad i_1 + i_2 = \sigma_i(i_1 + i_2 + i_0^L + i_1^L + i_2^L) \tag{47}$$

The rental market clears instantaneously. Therefore, the measure of renters must be equal to measure of investor-owners:

$$h_1 + h_0^L + h_1^L = i_2 + i_2^L \tag{48}$$

Lenders must be equal to the number of buyers with a mortgage in each stage:

$$l_{h1} = h_1^L, \quad l_{i1} = i_1^L, \quad l_{h2} = h_2^L, \quad l_{i2} = i_2^L \tag{49}$$

The laws of motion are:

$$\dot{s_1} = e + \pi_h(h_2^L + h_2) + \pi_i(i_2^L + i_2) - \delta s_1 - (h_1^L + h_1)m(\theta) - (i_1^L + i_1)m(\theta) \tag{50}$$

where e is the measure of new sellers (i.e. newly built houses).

$$\dot{h_1^L} = h_0^L q_h(\phi_h) - h_1^L m(\theta), \quad \dot{i_1^L} = i_0^L q_i(\phi_i) - i_1^L m(\theta) \tag{51}$$

$$\dot{h_2^L} = h_1^L m(\theta) - \pi_h h_2^L, \quad \dot{h_2} = h_1 m(\theta) - \pi_h h_2 \tag{52}$$

$$\dot{i_2^L} = i_1^L m(\theta) - \pi_i i_2^L, \quad \dot{i_2} = i_1 m(\theta) - \pi_i i_2 \tag{53}$$

In steady state, the 19 Equations in (43)-(53) pin down the 19 variables $(e, h_0^L, h_1^L, h_2^L, h_0, h_1, h_2, i_0^L, i_1^L, i_2^L, i_1, i_2, l_{h0}, l_{h1}, l_{h2}, l_{i0}, l_{i1}, l_{i2}, s_1)$ as functions of $(D, \theta, \phi_h, \phi_i)$ which are determined by the equilibrium equations in Section 6.5.

Appendix B Derivations

B.1 Prices and loans

Borrower-buyers and lenders solve the following maximization problems, taking as given loan amounts a_h and a_i:

$$\max_{p_h^L} [p_h^L - S_1]^{\beta_h} [H_2 - (p_h^L(1+\tau_h) - a_h) - H_1]^{1-\beta_h}, \quad \max_{p_i^L} [p_i^L - S_1]^{\beta_i} [I_2 - (p_i^L(1+\tau_i) - a_i) - I_1]^{1-\beta_i}$$

The first-order conditions are:

$$\begin{aligned} \beta_h[H_2^L - H_1^L - p_h^L(1+\tau_h) + a_h] &= (1+\tau_h)(1-\beta_h)[p_h^L - S_1], \\ \beta_i[I_2^L - I_1^L - p_i^L(1+\tau_i) + a_i] &= (1+\tau_i)(1-\beta_i)[p_i^L - S_1] \end{aligned} \tag{54}$$

Using the equilibrium conditions, we can rewrite the first-order-conditions as:

$$\begin{aligned} \beta_h[H_2^L - H_0^L - \frac{\chi_h}{q_h(\phi_h)} - p_h^L(1+\tau_h) + a_h] &= (1+\tau_h)(1-\beta_h)[p_h^L - S_1], \\ \beta_i[I_2^L - I_0^L - \frac{\chi_i}{q_i(\phi_i)} - p_i^L(1+\tau_i) + a_i] &= (1+\tau_i)(1-\beta_i)[p_i^L - S_1] \end{aligned} \tag{55}$$

Subtracting Equation (7) from (9) and plugging the equilibrium conditions (21), we obtain

$$H_2^L - H_0^L = \frac{R - rK + \varepsilon_h - \rho_h}{r + \pi_h} \tag{56}$$

Subtracting Equation (10) from (12) and plugging the equilibrium conditions (21), we obtain

$$I_2^L - I_0^L = \frac{R - rK + \varepsilon_i - \rho_i}{r + \pi_i} \tag{57}$$

Plugging (21), (56) and (57) into (55) and rearranging, we obtain the first equality in (27):

$$p_j^L = K + \frac{\beta_j}{(1+\tau_j)}\left[\frac{\varepsilon_j + R + \pi_j K}{r + \pi_j} - (1+\tau_j)K - \frac{\chi_j}{q_j(\phi_j)} - \frac{\rho_j}{r+\pi_j} + a_j\right], \quad j \in \{h, i\}$$

To obtain expressions for mortgage repayments, solve the surplus maximization problems taking into account the effect that a_j has on p_j^L according to equation (27):

$$\max_{a_h}[L_{h1} - L_{h0}]^{\psi_h}[H_1 - H_0]^{1-\psi_h}, \quad \max_{a_i}[L_{i1} - L_{i0}]^{\psi_i}[I_1 - I_0]^{1-\psi_i}$$

The first-order conditions are:

$$\psi_h[H_1^L - H_0^L] = (1-\psi_h)(1-\beta_h)[L_{h1} - L_{h0}], \quad \psi_i[I_1^L - I_0^L] = (1-\psi_i)(1-\beta_i)[L_{i1} - L_{i0}] \tag{58}$$

Plugging the equilibrium conditions 21, we obtain equilibrium credit market tightness in each market:

$$\phi_j^* = \frac{(1-\beta_j)(1-\psi_j)\chi_{lj}}{\psi_j \chi_j}, \quad j \in \{h, i\} \tag{59}$$

Subtracting Equation (7) from (8), plugging the equilibrium conditions 21 and rearranging, we obtain

$$H_1^L - H_0^L = -\frac{c_h}{r + m(\theta)} + \frac{m(\theta)}{r + m(\theta)}\left[\frac{R + \pi_h K + \varepsilon_h - \rho_h}{r + \pi_h} - p_h^L(1+\tau_h) + a_h\right] \tag{60}$$

Plugging the price equation (27):

$$H_1^L - H_0^L = -\frac{c_h}{r + m(\theta)} + \frac{(1-\beta_h)m(\theta)}{r + m(\theta)}\left[\frac{R + \pi_h K + \varepsilon_h - \rho_h}{r + \pi_h} - (1+\tau_h)K + a_h + \frac{\beta_h \chi_h}{(1-\beta_h)q_h(\phi_h)}\right] \tag{61}$$

Subtracting Equation (17) from (18), plugging the equilibrium conditions 21 and rearranging, we obtain

$$L_{h1} - L_{h0} = \frac{m(\theta)}{r + m(\theta)} \left[\frac{\rho_h}{r + \pi_h} - a_h \right] \tag{62}$$

Then can substitute out $H_1^L - H_0^L$ and $L_{h1} - L_{h0}$ in the first-order condition (58) using (61) and (62) to obtain:

$$\frac{\rho_h}{r + \pi_h} = a_h + \psi_h \left(\frac{R + \varepsilon_h + \pi_h K}{r + \pi_h} - (1 + \tau_h)K - \frac{c_h}{(1 - \beta_h)m(\theta)} + \frac{\beta_h \chi_h}{(1 - \beta_h)q_h(\phi_h)} \right) \tag{63}$$

which is the equation for loan amounts a_h in (25).

By a similar reasoning, we have:

$$I_1^L - I_0^L = -\frac{c_i}{r + m(\theta)} + \frac{(1 - \beta_i)m(\theta)}{r + m(\theta)} \left[\frac{R + \pi_i K + \varepsilon_i - \rho_i}{r + \pi_i} - (1 + \tau_i)K + a_i + \frac{\beta_i \chi_i}{(1 - \beta_i)q_i(\phi_i)} \right] \tag{64}$$

$$L_{i1} - L_{i0} = \frac{m(\theta)}{r + m(\theta)} \left[\frac{\rho_i}{r + \pi_i} - a_i \right] \tag{65}$$

and the loan amount a_i satisfies:

$$\frac{\rho_i}{r + \pi_i} = a_i + \psi_i \left(\frac{R + \varepsilon_i + \pi_i K}{r + \pi_i} - (1 + \tau_i)K - \frac{c_i}{(1 - \beta_i)m(\theta)} + \frac{\beta_i \chi_i}{(1 - \beta_i)q_i(\phi_i)} \right) \tag{66}$$

which is the equation for a_i in (25). If we substitute out the loan amounts in (27) using 63 and 66, we obtain the second equality in (27).

Buyers without a mortgage agreement and lenders solve the following maximization problems:

$$\max_{p_h} [p_h - S_1]^{\beta_h} [H_2 - p_h(1 + \tau_h) - H_1]^{1 - \beta_h}, \quad \max_{p_i} [p_i - S_1]^{\beta_i} [I_2 - p_i(1 + \tau_i) - I_1]^{1 - \beta_i} \tag{67}$$

The first-order conditions are:

$$\beta_h [H_2 - H_1 - p_h(1 + \tau_h)] = (1 + \tau_h)(1 - \beta_h)[p_h - S_1], \quad \beta_i [I_2 - I_1 - p_i(1 + \tau_i)] = (1 + \tau_i)(1 - \beta_i)[p_i - S_1] \tag{68}$$

Plugging the values for $H_2 - H_1$ and $I_2 - I_1$ we obtain (26).

B.2 The financial accelerator

Equalize $H_1^L - H_0^L$ and $I_1^L - I_0^L$ in the equilibrium conditions (21) to the forward expressions in equations (61) and (64) to obtain:

$$\frac{\chi_j}{q_j(\phi_j)} = -\frac{c_j}{r+m(\theta)} + \frac{(1-\beta_j)m(\theta)}{r+m(\theta)}\left[\frac{R+\pi_j K+\varepsilon_j-\rho_j}{r+\pi_j} - (1+\tau_j)K + a_j + \frac{\beta_j\chi_j}{(1-\beta_j)}\right]$$

$$\frac{\chi_{lj}}{\phi_j q_j(\phi_j)} = \frac{m(\theta)}{r+m(\theta)}\left[\frac{\rho_j}{r+\pi_j} - a_j\right]$$

Plug Equation (25) into the two equations above to obtain borrowers and lenders' entry equations (BE_j) and (LE_j).

To obtain the graph in Figure 9, note that (BE_j) and (LE_j) represent a negative and a positive relationship between ϕ_j and θ for given R and K, respectively. When $\theta \to 0$, (BE_j) and (LE_j) yield level of credit market tightness ϕ_j^B and ϕ_j^L such that:[29]

$$\frac{\chi_j}{q_j(\phi_j^B)} = \frac{(1-\psi_j)(1-\beta_j)\left[\frac{\varepsilon_j+R+\pi_j K(e)}{(r+\pi_j)} - (1+\tau_j)K(e)\right]}{[1-\beta_j(1-\psi_j)]} \tag{69}$$

and

$$\frac{\chi_{lj}}{\phi_j q_j(\phi_j^L)} = \frac{\psi_j\left[\frac{\varepsilon_j+R+\pi_j K(e)}{(r+\pi_j)} - (1+\tau_j)K(e)\right]}{[1-\beta_j(1-\psi_j)]} \tag{70}$$

When $\phi_j \to 0$ in (BE_j) and when $\phi_j \to \infty$ in (LE_j) market tightness is $\theta = \bar{\theta}$ such that:

$$c_j = m(\bar{\theta})(1-\beta_j)\left[\frac{\varepsilon_j + R + \pi_j K(e)}{r+\pi_j} - (1+\tau_j)K(e)\right] \tag{71}$$

Note that minimizing credit frictions ($q_j(\phi_j) \to \infty$ at any ϕ_j) yields the supremum of housing market tightness $\bar{\theta}$.

B.3 Shares of buyers' types

If we equalize Equations (46) and (48), we obtain:

$$\mathcal{H} = h_2 + h_2^L + i_2 + i_2^L \tag{72}$$

[29] For the existence of an equilibrium, assume that the parameter values are such that $\phi_j^B > \phi_j^L$.

Since there are no homeless people in the model, the number of households must be equal to the number of non-empty houses (owner-occupied or rented). In steady state, plugging Equations (52)-(53) into (50) yields

$$e = \delta s \tag{73}$$

The number of new houses equals the number of demolished houses in steady state. From Equations (45), (72) and (73), we can find:

$$s_1 = \frac{e}{\delta} = D - \mathcal{H}, \tag{74}$$

Then, using the definition of housing market tightness:

$$h_1 + h_1^L + i_1 + i_1^L = \theta(D - \mathcal{H}) \tag{75}$$

Now note from Equations (47), (52) and (53)

$$h_1 + h_1^L = \frac{\pi_h}{\pi_i - \pi_h}\left[\frac{\pi_i \mathcal{H}}{m(\theta)} - \theta(D - H)\right] \tag{76}$$

$$i_1 + i_1^L = \frac{\pi_i}{\pi_i - \pi_h}\left[\theta(D - H) - \frac{\pi_h \mathcal{H}}{m(\theta)}\right] \tag{77}$$

Also,

$$h_1 = \frac{\sigma_h \left[1 + \frac{m(\theta)}{\pi_h} + \frac{m(\theta)}{q_h(\phi_h)}\right]}{(1 - \sigma_h)\left[1 + \frac{m(\theta)}{\pi_h}\right]} h_1^L \tag{78}$$

$$i_1 = \frac{\sigma_i \left[1 + \frac{m(\theta)}{\pi_i} + \frac{m(\theta)}{q_i(\phi_i)}\right]}{(1 - \sigma_i)\left[1 + \frac{m(\theta)}{\pi_i}\right]} i_1^L \tag{79}$$

Finally, using Equations (76)-(79) and (74) we can find the shares of buyers:

$$\frac{h_1}{h_1^L + h_1 + i_1^L + i_1} = \frac{\sigma_h \left[1 + \frac{m(\theta)}{\pi_h} + \frac{m(\theta)}{q_h(\phi_h)}\right]}{\left[1 + \frac{m(\theta)}{\pi_h} + \frac{\sigma_h m(\theta)}{q_h(\phi_h)}\right]} \frac{\pi_h}{(\pi_i - \pi_h)}\left[\frac{\pi_i \mathcal{H}\delta}{\theta m(\theta) e} - 1\right] \tag{80}$$

$$\frac{i_1}{h_1^L + h_1 + i_1^L + i_1} = \frac{\sigma_i \left[1 + \frac{m(\theta)}{\pi_i} + \frac{m(\theta)}{q_i(\phi_i)}\right]}{\left[1 + \frac{m(\theta)}{\pi_i} + \frac{\sigma_i m(\theta)}{q_i(\phi_i)}\right]} \frac{\pi_i}{(\pi_i - \pi_h)}\left[1 - \frac{\pi_h \mathcal{H}\delta}{\theta m(\theta) e}\right] \tag{81}$$

$$\frac{h_1^L}{h_1^L + h_1 + i_1^L + i_1} = \frac{(1-\sigma_h)\left[1+\frac{m(\theta)}{\pi_h}\right]}{\left[1+\frac{m(\theta)}{\pi_h}+\frac{\sigma_h m(\theta)}{q_h(\phi_h)}\right]} \frac{\pi_h}{(\pi_i-\pi_h)} \left[\frac{\pi_i \mathcal{H}\delta}{\theta m(\theta) e} - 1\right] \tag{82}$$

$$\frac{i_1^L}{h_1^L + h_1 + i_1^L + i_1} = \frac{(1-\sigma_i)\left[1+\frac{m(\theta)}{\pi_i}\right]}{\left[1+\frac{m(\theta)}{\pi_i}+\frac{\sigma_i m(\theta)}{q_i(\phi_i)}\right]} \frac{\pi_i}{(\pi_i-\pi_h)} \left[1 - \frac{\pi_h \mathcal{H}\delta}{\theta m(\theta) e}\right] \tag{83}$$

B.4 Wealthy households' and investors' mortgage choice

In this section, we compare the equilibrium values of household buyers searching for a seller with and without a mortgage agreement. Denote H_1^M the value of a household buyer. First, note that in equilibrium:

$$H_2 = \frac{y + \varepsilon_h + \pi_h K + \pi_h H_1}{r + \pi_h} \tag{84}$$

$$H_2^L + a_h = \frac{y + \varepsilon_h - \rho_h + \pi_h K + \pi_h H_1^L}{r + \pi_h} + a_h \leq \frac{y + \varepsilon_h + \pi_h K + \pi_h H_1^L}{r + \pi_h} \tag{85}$$

where the inequality stems from the fact that the present discounted value of a loan for a bank has to be positive $\frac{\rho_h}{r+\pi_h} - a_h > 0$. This is a necessary condition for the existence of an equilibrium in which lenders participate. Then, from the first-order-condition in the Nash bargaining and (84)

$$\begin{aligned} rH_1 &= y - R - c_h + m(\theta)[H_2 - H_1 - p_h] = y - R - c_h + m(\theta)(1-\beta_h)[H_2 - H_1 - K] \\ &= y - R - c_h + m(\theta)(1-\beta_h)\left[\frac{y + \varepsilon_h + \pi_h K - rH_1}{r + \pi_h} - (1+\tau_h)K\right] \end{aligned} \tag{86}$$

Rearranging:

$$H_1 = \frac{y - R - c_h + m(\theta)(1-\beta_h)\left[\frac{y+\varepsilon_h+\pi_h K}{r+\pi_h} - (1+\tau_h)K\right]}{r + \frac{m(\theta)(1-\beta_h)r}{r+\pi_h}} \tag{87}$$

Likewise, from the first-order-condition in the Nash bargaining and (85):

$$\begin{aligned} rH_1^L &= y - R - c_h + m(\theta)[H_2^L - H_1^L - p_h + a_h] = y - R - c_h + m(\theta)(1-\beta_h)[H_2^L + a_h - H_1^L - K] \\ &\leq y - R - c_h + m(\theta)(1-\beta_h)\left[\frac{y + \varepsilon_h + \pi_h K - rH_1^L}{r + \pi_h} - (1+\tau_h)K\right] \end{aligned} \tag{88}$$

Rearranging:

$$H_1^L \leq \frac{y - R - c_h + m(\theta)(1-\beta_h)\left[\frac{y+\varepsilon_h+\pi_h K}{r+\pi_h} - (1+\tau_h)K\right]}{r + \frac{m(\theta)(1-\beta_h)r}{r+\pi_h}} = H_1 \tag{89}$$

A wealthy buyer will always prefer to search and buy without a mortgage, as long as the search value is positive and the lender's bargaining power is not 0. The intuition is that the buyer prefers not share any of the transaction surplus with the lender and therefore will never ask for a mortgage in case she has sufficient wealth to purchase a property outright.

Appendix C Additional tables

Table C1: Effect of stamp-duty surcharge on log listing price

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	0.061	0.039	0.038	0.058	-0.101	-0.101
	(0.073)	(0.062)	(0.063)	(0.074)	(0.086)	(0.084)
Ant.*Share Rented			-0.005			
			(0.018)			
N	1,959,855	1,959,855	1,959,855	1,598,444	1,598,444	1,598,444
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log listing price as the dependent variable. Controls (property level): quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C2: Effect of stamp-duty surcharge on number of quarterly constructions of private buildings

	(1)	(2)	(3)	(4)	(5)
Post*Share Rented	25.660 (70.549)	-16.705 (55.080)	-27.203 (67.707)	-25.026 (61.221)	-27.152 (70.672)
Ant.*Share Rented			-59.983 (95.508)		
N	8,108	8,108	8,108	6,804	6,804
LA controls	NO	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES
Post*London	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA

Notes: This table reports results from OLS regressions of Equation (4) using the log of the number of days between the transaction date and the listing date as the dependent variable. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C3: Effect of stamp-duty surcharge on number of log quarterly transactions, controlling for *Post August 2018* $* \, Midlands$

	(1)	(2)	(3)	(4)	(5)
Post*Share Rented	-0.587*** (0.145)	-0.640*** (0.144)	-0.471** (0.186)	-0.572*** (0.195)	-0.479** (0.240)
Ant.*Share Rented			0.606*** (0.190)		
N	8,700	8,700	8,700	7,308	7,308
LA controls	NO	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES
Post*London	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA

Notes: This table reports results from OLS regressions of Equation (4) using the log of the number of days between the transaction date and the listing date as the dependent variable. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C4: Effect of stamp-duty surcharge on number of quarterly constructions of private buildings, controlling for *Post August 2018* $* \, Midlands$

	(1)	(2)	(3)	(4)	(5)
Post*Share Rented	26.625	-16.590	-27.250	-24.809	-27.048
	(70.458)	(54.664)	(67.047)	(60.650)	(69.842)
Ant.*Share Rented			-59.994		
			(95.421)		
N	8,108	8,108	8,108	6,804	6,804
LA controls	NO	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES
Post*London	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA

Notes: This table reports results from OLS regressions of Equation (4) using the log of the number of days between the transaction date and the listing date as the dependent variable. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C5: Effect of stamp-duty surcharge on log paid price

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	-0.054**	-0.086***	-0.083***	-0.090***	-0.102***	-0.102***
	(0.023)	(0.018)	(0.018)	(0.020)	(0.023)	(0.022)
Ant.*Share Rented			0.026***			
			(0.009)			
N	1,950,769	1,950,769	1,950,769	1,590,874	1,590,874	1,590,874
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log paid price as the dependent variable. Controls (property level): log listing price, quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C6: Effect of stamp-duty surcharge on log listing price

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	0.064	0.039	0.039	0.058	-0.101	-0.101
	(0.073)	(0.062)	(0.063)	(0.074)	(0.086)	(0.084)
Ant.*Share Rented			-0.005			
			(0.018)			
N	1,959,855	1,959,855	1,959,855	1,598,444	1,598,444	1,598,444
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log listing price as the dependent variable. Controls (property level): quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C7: Effect of stamp-duty surcharge on log days to sell

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	0.165	0.259**	0.270**	0.318***	0.287*	0.287**
	(0.113)	(0.104)	(0.106)	(0.122)	(0.147)	(0.137)
Ant.*Share Rented			0.80*			
			(0.041)			
N	1,994,783	1,994,783	1,994,783	1,628,019	1,628,019	1,628,019
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log of the number of days between the transaction date and the listing date as the dependent variable. Controls (property level): quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C8: Effect of stamp-duty surcharge on log price paid by owner-occupiers

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	-0.041*	-0.072***	-0.069***	-0.079***	-0.094***	-0.094***
	(0.022)	(0.017)	(0.017)	(0.020)	(0.022)	(0.021)
Ant.*Share Rented			0.023**			
			(0.010)			
N	1,226,749	1,226,749	1,226,749	978,144	978,144	978,144
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log listing price as the dependent variable. Controls (property level): log listing price, quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table C9: Effect of stamp-duty surcharge on log price paid by buy-to-let investors

	(1)	(2)	(3)	(4)	(5)	(6)
Post*Share Rented	-0.080***	-0.114***	-0.109***	-0.115***	-0.126***	-0.126***
	(0.024)	(0.019)	(0.019)	(0.022)	(0.026)	(0.026)
Ant.*Share Rented			0.032**			
			(0.015)			
N	342,803	342,803	342,803	283,801	283,801	283,801
LA controls	NO	YES	YES	YES	YES	YES
Donut hole	NO	NO	NO	YES	YES	YES
Post*London	YES	YES	YES	YES	YES	YES
Post*Second shares	YES	YES	YES	YES	YES	YES
Post*EU shares	NO	NO	NO	NO	YES	YES
S.E.	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Clustered at LA	Spatial HAC (100km)

Notes: This table reports results from OLS regressions of Equation (3) using the log listing price as the dependent variable. Controls (property level): log listing price, quadratics in latitude and longitude, size, number of rooms, energy performance, type of property, new, leasehold, fireplace, type of wall, extensions. Controls (LA level): lagged population, GDP per capita, housing stock, council total expenditures, council housing expenditures, council tax. In columns (1)-(5), s.e. are clustered at local authority level. In column (6), I allow spatial HAC s.e. to be serially correlated over the entire period. Spatial weighting kernels are assumed to decay linearly. Zero spatial correlation is assumed beyond 100km. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Appendix D Additional figures

Figure D1: Real housing price growth in OECD countries

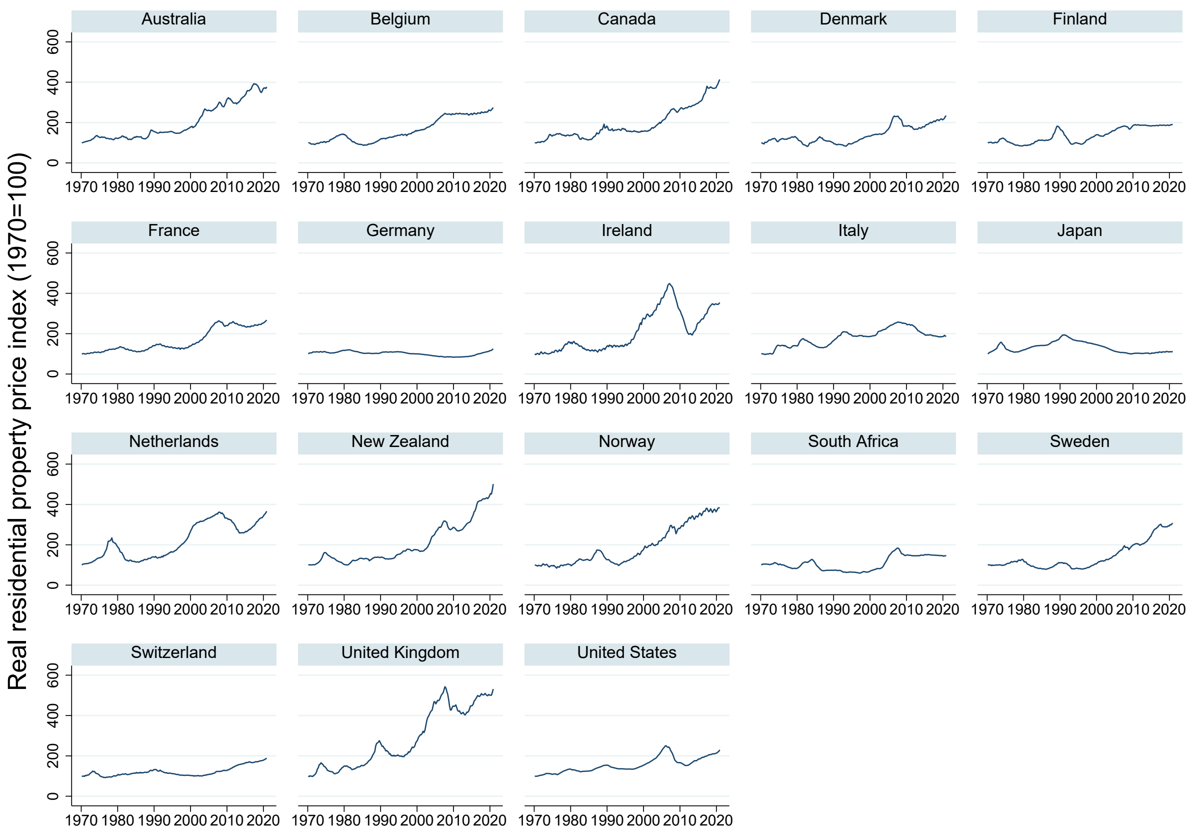


Figure D2: Housing price growth in the United States

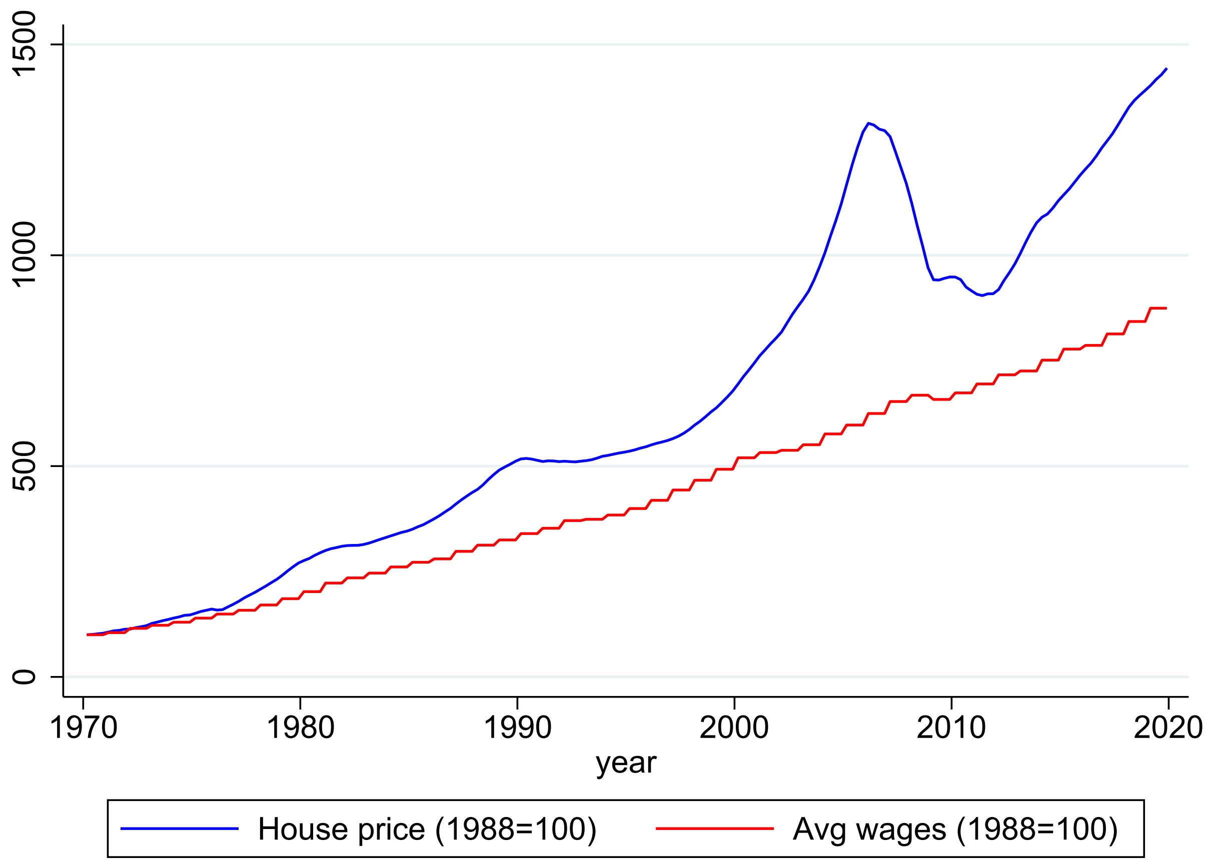


Figure D3: Number of dwellings by type of tenure

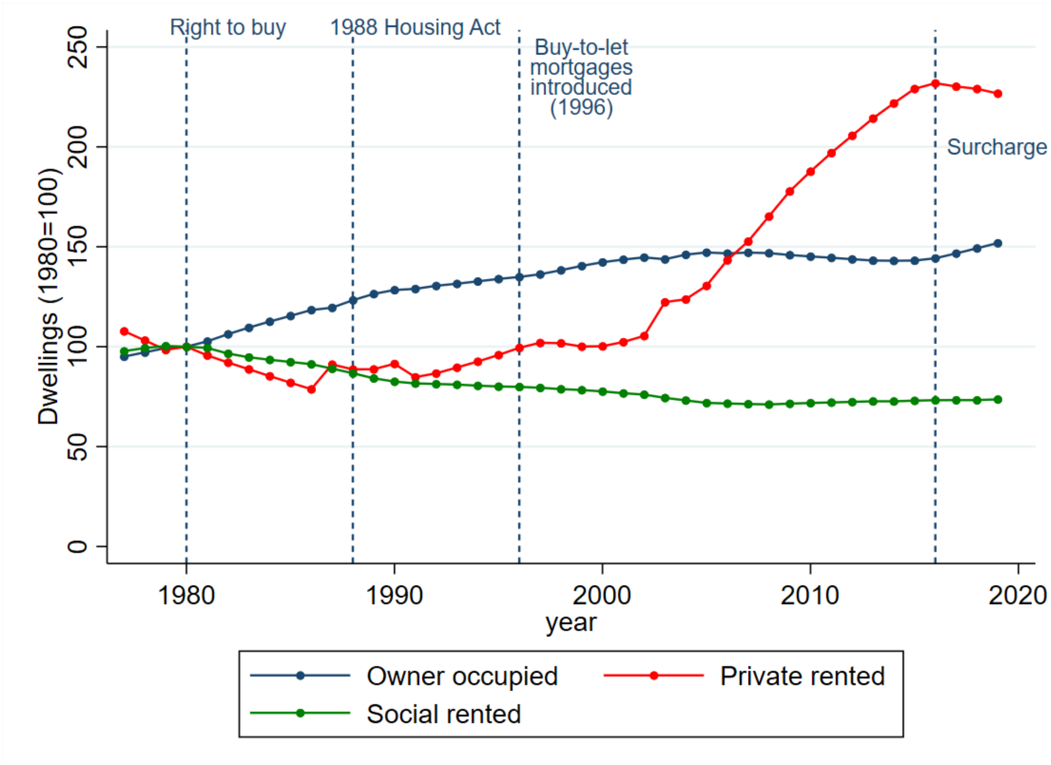


Figure D4: Housing price growth by region in England

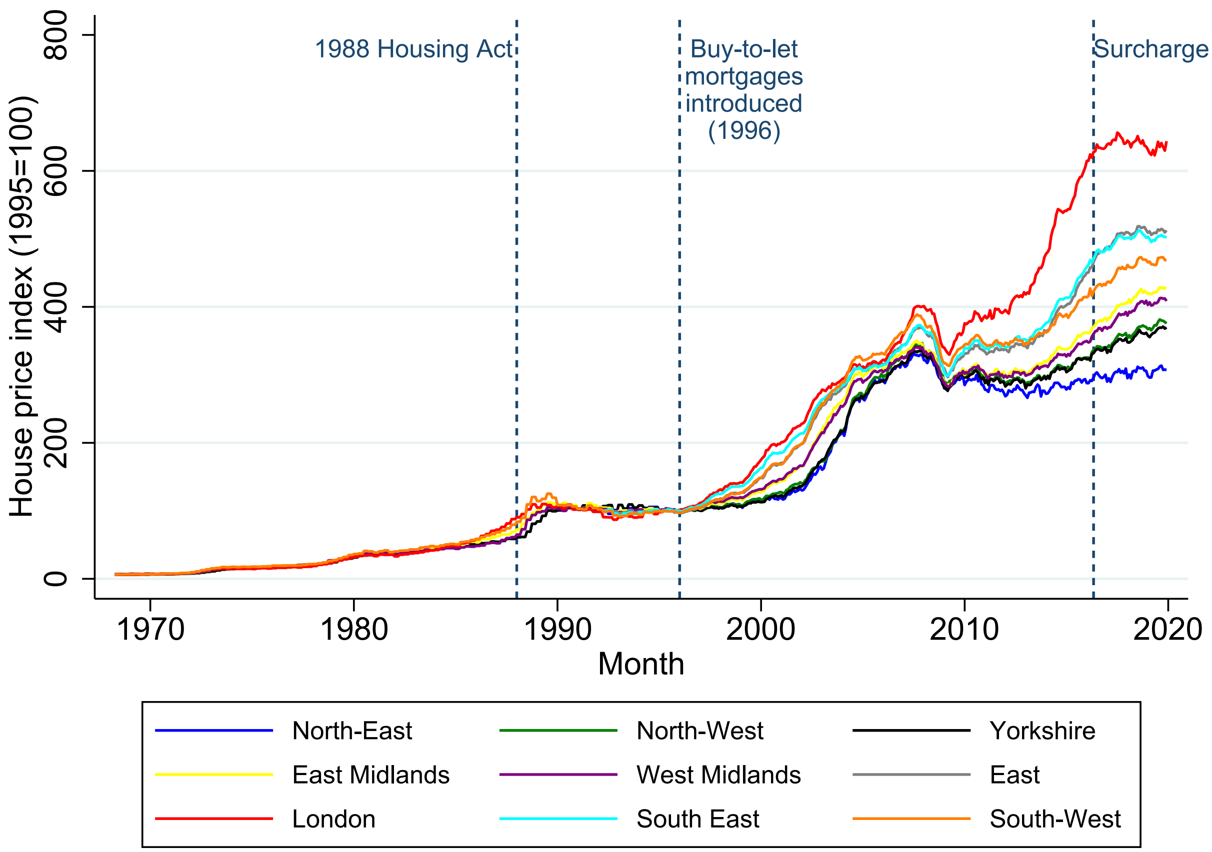


Figure D5: Stamp-duty surcharge liability

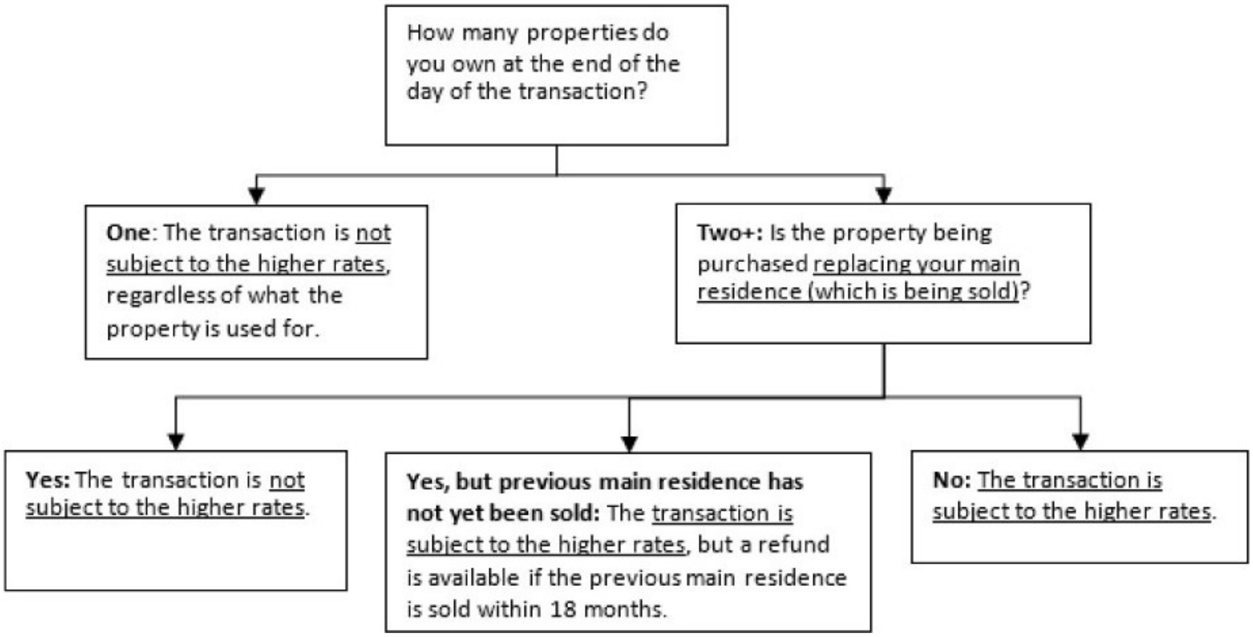


Figure D6: Stamp duty anticipation effects

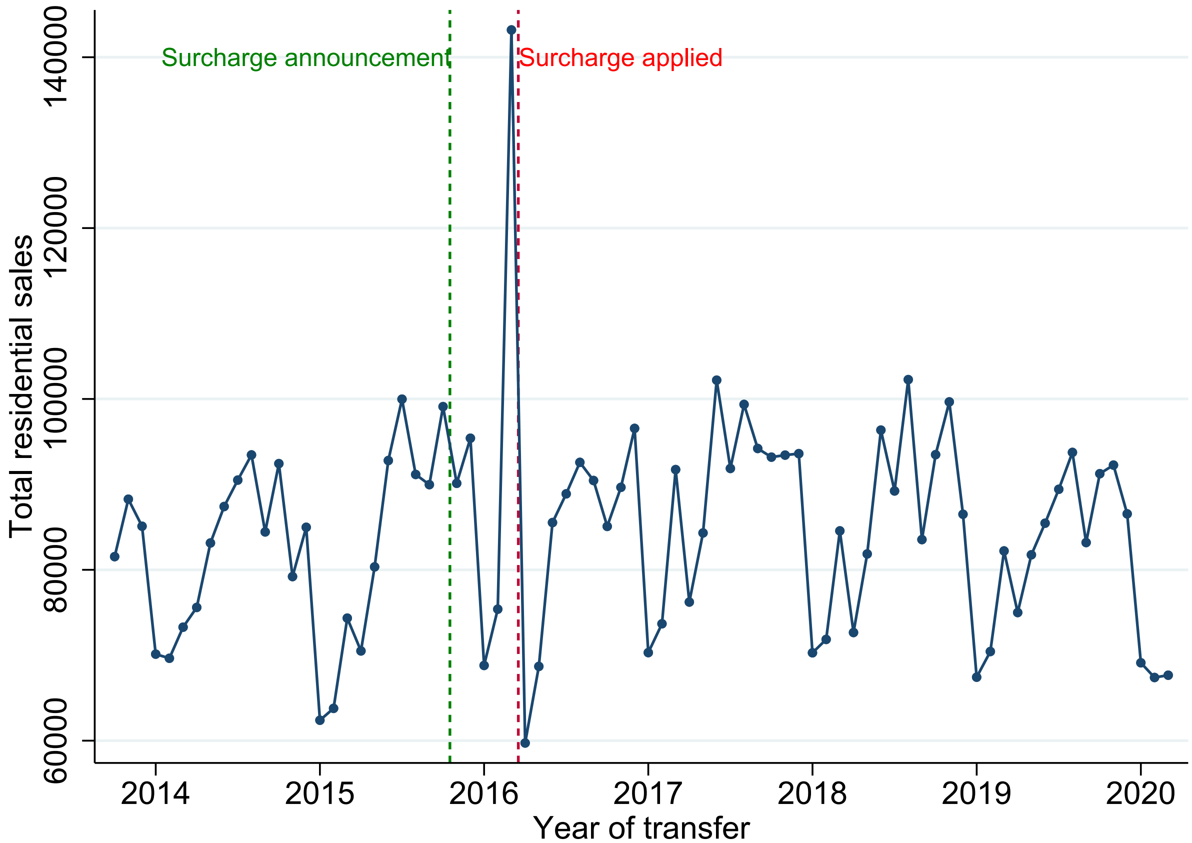
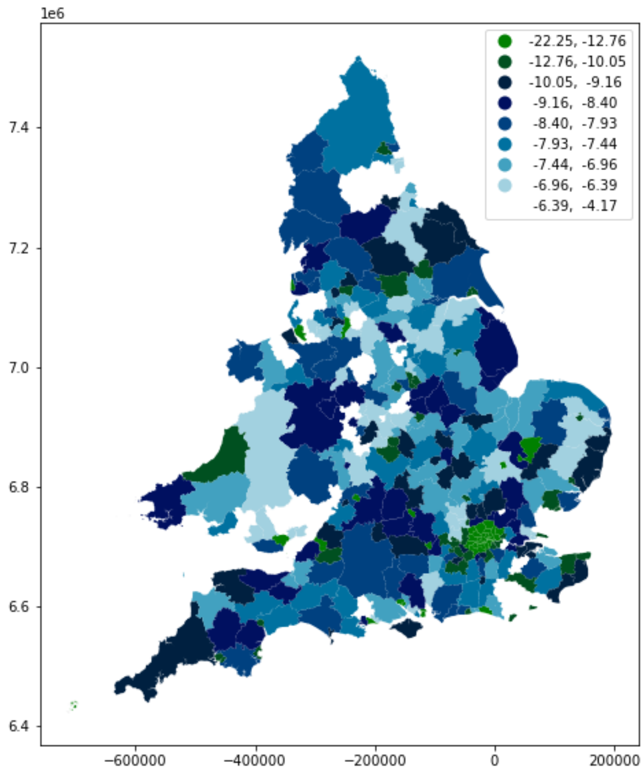


Figure D7: Heterogeneous effects of the SDLT surcharge

(a) Heterogeneous effects on transactions



(b) Heterogeneous effects on paid prices

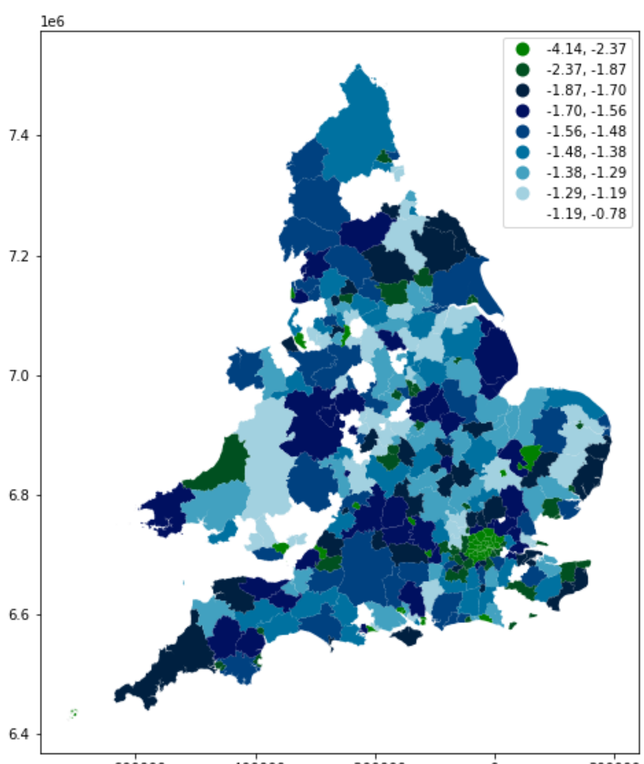


Figure D8: Effect on listing prices