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Credit Constraints and the Composition of Housing Sales. Farewell to First-time Buyers? *

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Abstract

During the housing bust of 2008–2009, housing prices and transaction volumes fell across the United Kingdom. While the drop in prices was similar across housing types, transaction volumes fell more for units at the lower end of the market. I document this fact and provide panel and instrumental variable estimates showing its link with tightening credit conditions in England and Wales during 2008. I then use an overlapping-generations framework to relate the change in the composition of sales with the reduction in loan-to-value ratios by British banks and to derive additional predictions. As down-payment requirements increase, young households with scarce financial resources are priced out by older owners who retain their previous houses as rental properties when trading up. Recent changes in aggregate housing tenure, disaggregated changes in renting, and sales in areas with different age compositions, are consistent with these predictions. The results presented here show how the composition of sales changes over the housing cycle and may inform ongoing policy discussions about reduced access to home-ownership by the young.

Keywords: Housing markets, housing transactions, credit constraints.

JEL codes: R31, G21

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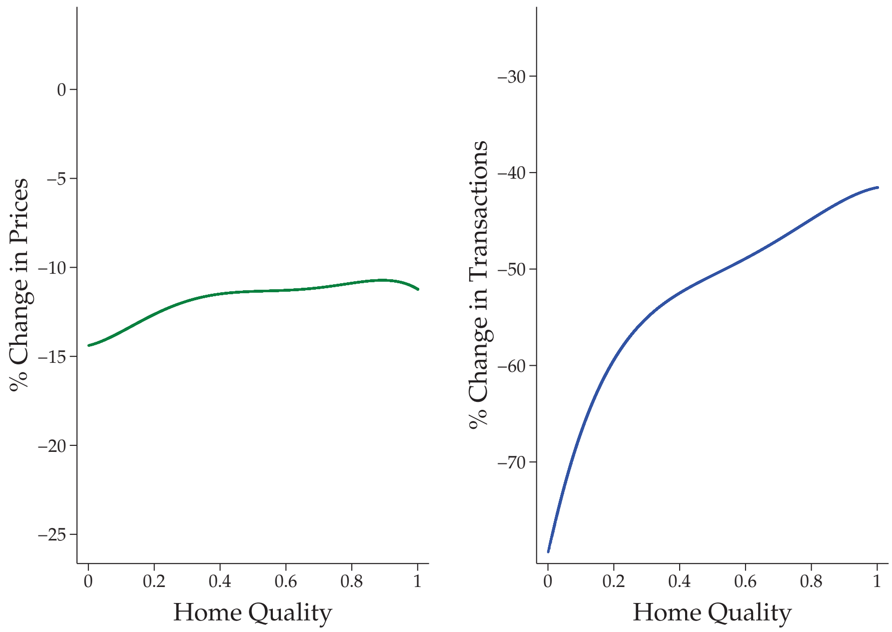
1. Introduction

House prices and transaction volumes fall during recessions and rise during expansions.[1] This paper begins by showing that these changes feature a previously overlooked heterogeneity across different quality segments of the housing market. During the housing bust of 2008–2009, housing prices and transaction volumes fell across the entire United Kingdom. While the initial reduction in prices was similar across housing types, transaction volumes fell more for houses at the lower end of the market. To document this, I use an administrative dataset containing all private housing market transactions in England and Wales. Figure 1 illustrates the finding. The left panel plots the median percentage change in prices between 2007 and 2009 against a measure of housing quality. We see that the relationship is slightly positive but close to flat. The right panel shows the same plot for the percentage change in transactions, where we see that the drop in sales was substantially larger for lower-quality houses. This differential decrease in transactions affected the composition of sales in subsequent years.

In this paper I show that these changes are the result of the tightening of credit conditions in the United Kingdom during 2008, which lead to a sharp reduction of the Loan-to-Value ratios (LTVs) on mortgages offered by British banks to First-time Buyers (FTBs). I use city-level data on changes in LTVs to estimate the effect of this tightening of credit conditions on transaction volumes and prices across segments of the housing market. My findings indicate that a 1 percentage point reduction in mean Loan-to-Value ratios reduced transactions of average quality housing by up to 1.2%. However, for housing with quality a standard deviation below the mean, the same change in LTVs generated a reduction of 3% in volumes. This heterogeneous effect is consistent with the changing composition of sales after 2008.

[1] Evidence of time series correlation between sale volumes and prices is presented in Berkovec and Goodman (1996), Lamont and Stein (1999) for the United States and Andrew and Meen (2003), Ortalo-Magne and Rady (2004), Benito (2006) for the United Kingdom.

Figure 1: Change in Prices and Transactions by Housing Quality



Notes: **Left:** The vertical axis represents the proportional change in prices between 2007 and 2009 and the horizontal axis measures within-city quality rank calculated as shown in section 3. The line represents a polynomial fitted using a median regression of changes in prices on the quality rank (correlation equal to 4%). **Right:** The vertical axis represents the change in transactions between 2007 and 2009 and the horizontal axis measures within-city quality ranks. The line represents a polynomial fitted using a median regression of changes in transactions on the quality rank (correlation equal to 19%).

In order to explore the mechanisms in operation behind this finding and to derive additional implications, I propose a tractable housing ladder model with borrowing constraints and renting in which credit conditions affect the composition of sales. In the model, greater down-payment requirements hinder house purchases by young households with lower levels of wealth. In turn, older and wealthier households facing lower prices become 'accidental landlords', who keep their previous properties and rent them out when moving up the housing ladder. The fact that these entry-level houses are rented instead of being sold drives the change in the composition of transactions: sales of lower quality houses make up a smaller fraction of the total when down-payment requirements increase. In addition to reproducing the stylized fact outlined above, the model delivers additional predictions that are tested empirically: tighter credit leads to an increase in private renting, a negative cross-sectional correlation between renting and transactions, and less purchases by the young. I exploit the high level of geographical disaggregation in my transactions dataset to test these implication and find support for the underlying mechanism.

The last decade has seen a consistent reduction in home-ownership rates for young households in the United Kingdom. While these households still aspire to become owners, high prices and deposit constraints stand in the way of these aspirations. By examining the evolution of transactions in different segments of the housing market, this paper sheds light on the mechanism leading to this change by tying the composition of sales, credit conditions and the supply of rented housing. In doing so, I also provide a mechanism that explains why young generations in England and Wales have been priced out of owner-occupation after 2008.

This study contributes to the empirical literature studying the heterogeneity of housing cycles across different market segments. Previous studies have documented how the prices for housing of different quality change over the cycle, particularly during boom periods such as the early 2000s in the United States.[2] For example, several studies seek to explain within-city changes in prices during the housing boom (e.g. Ferreira and Gyourko (2011), Glaeser, Gottlieb and Tobio (2012), Genesove and Han (2013) and Guerrieri, Hartley and Hurst (2013)). In recent work, Landvoigt, Piazzesi and Schneider (2015) focus on matching the joint distributions of wealth, income and qualities using an assignment model which takes the quality distribution of traded units as given. Relative to this literature, my paper focuses specifically on understanding and explaining changes in the composition of transactions. Incorporating transactions into the analysis is relevant because, in the recent UK housing bust, the disparity between segments is larger in the evolution of transaction volumes than in the evolution of prices.

My contribution is also related to the empirical and theoretical literatures on the effects of credit constraints on housing prices and transaction volumes. Stein (1995) presents a partial equilibrium

[2] There are some exceptions. Smith and Tesarek (1991) study the evolution of housing prices across qualities during a Houston boom-bust episode in the 80s. Case and Mayer (1996) study cross-sectional differences in the evolution of prices over time and relate them to changes in supply and demand factors.

model linking down-payment requirements to the number of sales. Its mechanism is integrated into a housing model with endogenous prices in Ortalo-Magne and Rady (1999) and Ortalo-Magne and Rady (2006). In these studies the change in the time series for transactions emerges from capital gains (or losses) on starter homes. I propose an alternative mechanism relating borrowing constraints and sales by emphasizing the link between housing ladder transitions and the supply of housing in the rental market. In this sense, I draw attention to the relationship between the composition of sales and changes in home-ownership rates. Moreover, the qualitative predictions from my model refer to the variation in the impact of borrowing constraints on sale volumes across housing types rather than on the time series of total transactions.[3]

Recent work has documented the effect of credit supply shocks on residential and other markets. Mian and Sufi (2009) use spatially disaggregated credit demand measures to study the effect of a credit expansion on the growth in housing prices during the boom and defaults during the bust. Mondragon (2017) and Kleiner (2015) use different methods to identify how lender level shocks can impact the housing, credit and labour markets. My contribution to this literature is to focus specifically on the impact of changing credit conditions on different segments of the housing market, tenure choice and the composition of sales.

Finally, this paper informs the literature on house price indices. It is broadly acknowledged that changes in composition must be taken into account when constructing housing price indices (see for example Case (1986) and Case and Shiller (1989), see also Hill (2012) for a survey). Gatzlaff and Haurin (1997) argue that traditional hedonic or repeat sales methods which use characteristics to adjust for changes in composition may still face selection problems which yield biased measures of the price of the housing stock at any point in time. Kleiner (2014) documents a change in composition in the United States in the period between 2000 and 2006 and provides a method to

[3]Chambers, Garriga and Schlagenhauf (2009) propose a quantitative model with heterogeneous housing types and renting to understand the effect of mortgage markets innovations on US home-ownership rates. Their analysis does not focus on studying the composition of sales or the dynamics of transactions.

construct a repeat-sales price index which is robust to these changes. Despite the variety of methods available to deal with changes in composition, little is known about how and why the composition of transactions actually changes over the cycle. This paper describes these changes and provides evidence relating them to credit conditions. The documented change in the composition of sales after 2008 implies that mean prices undervalue the extent of the housing slump relative to quality-adjusted indices.

The data used in the empirical sections of this paper is presented in section 2. To measure transaction volumes and prices, I use the Price Paid Dataset from the English and Welsh Land Registry. This dataset covers all regular residential transactions in England and Wales. High coverage is essential in order to study possible changes in transactions for different qualities over time.

In Section 3, I document how housing prices and transactions changed between 2007 and 2009 for different segments within English and Welsh metropolitan areas. To do so, I propose two different estimates of unobserved quality, both yielding similar results. Housing of different qualities experienced a similar fall in prices. In contrast, transactions fell substantially more for lower quality units, changing the composition of sales.

The findings are interpreted in the context of recent academic and policy discussions highlighting the role of credit conditions in housing markets and their effect on young households. In section 4, I use data from a mortgage provider and exploit heterogeneity across cities in the change of Loan-to-Value ratios to estimate the effect of credit tightening on the composition of sales. Panel and instrumental variable estimates show that the reduction in LTVs to first-time buyers had a large negative effect on transactions of low quality dwellings. I do not observe an heterogeneous effect of changes in LTVs on prices.

Section 5 presents a housing ladder model with renting and credit constraints in which households differ in age and income. I use this to show that steady states with tighter lending conditions have a lower number of first-time buyers, a right-shifted composition of traded qualities and higher levels of renting. In addition, tighter credit leads to more *let-to-buy* (households which keep their starter houses and rent these when trading up). These results are driven by the pricing out of young buyers by wealthier, older households when credit is tighter.

Evidence supporting the underlying mechanism is presented in Section 6. Using disaggregated information on the evolution of housing tenure, I show a strong negative correlation between the fall in transactions and the increase in renting. Using data on changes in LTV by city, I relate credit tightening to changes in rental markets. Finally, I show that the change in transactions had a clear age profile.

Other explanations which could also account for the change in composition of housing sales are discussed in Section 7. Finally, Section 8 concludes by discussing policy implications and avenues for further research.

2. Data

Throughout most of this paper I use the Land Registry's Price Paid dataset covering the vast majority of residential transactions in England and Wales.[4] It includes market transactions for the 1995-2013 period recording the transaction price, address, an indicator of dwelling type (detached, semi-detached, terrace or flat), contract type (freehold or leasehold) and whether the house is a new build.

The Price Paid data for the 1995-2013 period includes a total of 18,744,353 transactions. Given that leasehold transactions do not include information on the lease term I exclude them from the analysis. I also exclude new build sales as they are related to construction activity. As will be shown below, neither of these restrictions have a qualitative effect on my findings. Finally, I drop all transactions missing location data. These sample restrictions are summarized in Table A1 in

[4]The Price Paid dataset excludes properties which are likely to be sold at a discount either because they are transfers or conveyances (e.g. transfers under court order, sale of shares of a property), leases under 7 years of their expiry date, transfers of more than one property as part of a portfolio or right-to buy properties. These transactions amount to roughly an 80% of the total transactions reported by HM Revenue & Customs.

Appendix A. The final transactions dataset encompasses a total of 12,537,180 transactions for the 1995-2013. I also build a repeat-sales sample of units sold at least twice over my sample period. There are a total of 9.4342.390 transactions in my repeat-sales dataset.

I complement this with information from other sources. Disaggregated population counts by age group are obtained from the Office for National Statistics (ONS). Data on labour market performance is obtained from the Annual Population Survey and the Annual Survey of Hours and Earnings.[5] Disaggregated data on housing tenure distributions is taken from the 2001 and 2011 census, while aggregate tenure is obtained from the English Housing Survey. Internal migration data is obtained from the ONS. With respect to information on credit market conditions, I use data on mortgages granted by Nationwide - one of the largest mortgage providers in the United Kingdom - to measure LTV ratios to first time buyers in 1999, 2007 and 2009. Figures A8 and A7, in Appendix A, show that this dataset is broadly representative of the spatial distribution of transactions and the trends in lending behaviour over the 2007 to 2009 period.

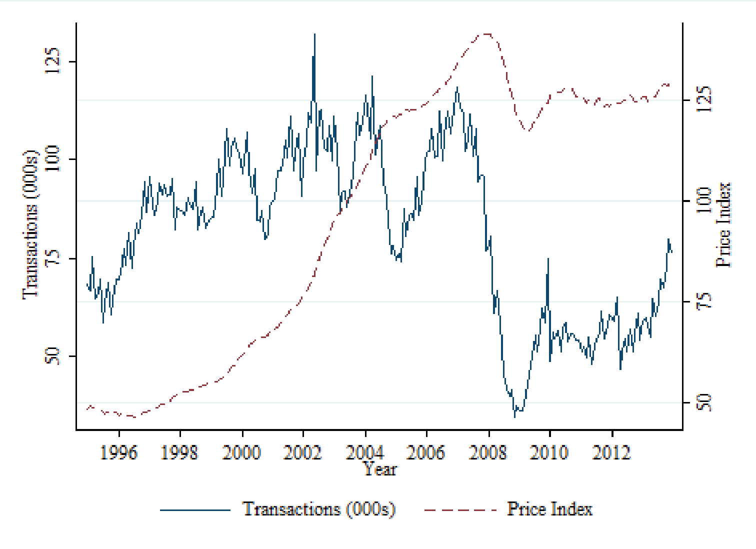
Geographies

Throughout the paper I use data at different levels of geographical disaggregation. Aggregate quantities refer to England and Wales only. My definition of spatial housing markets or cities is based on Travel-to-Work Areas (TTWAs). TTWAs are analogous to commuting zones for the United States and are built using information on commuting patterns. There are a total of 186 travel-to-work areas in England and Wales. Throughout the paper I use the terms city and TTWA interchangeably.

Within-TTWAs I use information at the lower super output area (LSOA), postcode sector and postcode district levels. LSOAs are spatial units defined for the collection and publication of data by the ONS. They represent the smallest area at which the 2011 census data was disclosed. There

[5] Information on labour markets is usually available at the local authority level. In the small minority of cases in which local authority data is not available I impute the corresponding regional figure (20/300 cases for unemployment).

Figure 2: Evolution of Transactions and Prices



Note: Data for England and Wales. Left vertical axis corresponds to transaction volumes and right vertical axis corresponds to prices. Number of transactions in thousands. The price index is the repeat-sales index built by the Land Registry (base set to June 2003).

are 34,753 LSOAs in England and Wales, of which 34,374 have at least one transaction in the Land Registry dataset. Postcode sectors (PS) and postcode districts are aggregations of postcodes.[6]

I use the National Statistics Postcode Lookup Directory (PLD) to match this geographical information with the Land Registry dataset. The PLD links postcodes with all the relevant geographies in the UK.

The Housing Market of England and Wales

Figure 2 shows the series of de-seasonalized housing transactions and prices for the 1995-2013 period. Before the financial crisis, the monthly number of sales increased from around 70,000 in 1995 to 100,000 after 1998 and then oscillated around this figure until the last quarter of 2007.

After a brief period of stagnation house prices began to drop steadily and by April 2009 the Land Registry's index reached its trough.[7] This supposed a 17% drop in nominal housing prices (20.4%

[6]On average a postcode sector contains 2,995 households housing 7,272 people. There are 8,464 PS with at least one transaction in the Land Registry dataset. Postcode districts are aggregations of postcode sectors. There are roughly 2,900 postcode districts in the UK and 2,345 postcode districts with positive sales in my Land Registry dataset.

[7]The previous housing downturn in the United Kingdom had taken place in the late 80s when rising mortgage rates and a worsening of labour market conditions affected affordability in UK housing markets (Jowsey (2011)).

in real terms). Simultaneously, 2008 saw a fast decrease in transaction volumes: December 2008 recorded 51% less housing purchases than the same month in 2007. The change in transactions was coupled with a sharp decrease in listings during 2008 and an increase in time on the market for listed houses (see Figure A1 in Appendix A) . More than six years after the bust started, prices and transactions had not fully recovered. In 2013, yearly sales were still lower than in every year between 1997 and 2007.

Regarding trends in housing tenure, the 1981-2001 period saw an increase in home-ownership from 59% to 69%. Several studies point to the relaxation of credit conditions over the 80s and 90s, as the source of this change in tenure (see Muellbauer and Murphy (1997), Ortalo-Magne and Rady (1999), Stephens, Whitehead and Munro (2005)). However, in 2001 the rate of home-ownership started to decrease and private renting recovered. Between 2002 and 2008, the percentage of households living as renters increased from 10% to 12.8% , mainly through increases in rented stock resulting from purchases by home-owners for investment purposes. Renting increased faster during the crisis, going from 12.8% to 16.4% in 2012. Rented units usually have lower selling prices than owner-occupied units. This owes in large part to differences in physical characteristics, as reported in Halket, Nesheim and Oswald (2015) and shown in Figure A2 in Appendix A.

3. Stylised Fact: The Bust by Housing Qualities

In this section I study how the downturn affected different segments of the housing market. In particular, I study how prices and transactions fell between 2007 and 2009 for houses of different quality levels.

In order to study how transactions and prices of different qualities evolved during the crisis I first need a definition of quality that can be applied to my transaction data. I will define the quality of a house as a fixed, unobservable attribute which is desirable for households seeking to reside there and, hence, will be positively correlated with prices in equilibrium. Note that I am not seeking to estimate quality as a structural parameter in household preferences but rather to obtain a classification of houses in terms of this unobservable trait.

For this purpose, suppose the price for a unit i sold in quarter t can be decomposed as follows:

$$p_{it} = \delta_{it}^{TTWA} + \alpha_i + \xi_{it}.$$

Where p_{it} is the logarithm of the transaction price and δ_t^{TTWA} is a set of (TTWA specific) time dummies. The error term ξ_{it} captures random variation in the transaction price that is not fixed or unit specific (e.g.: specific to the buyer-seller match). Quality is defined as α_i and is fixed and unobservable. In the estimation of quality, I will only use data from the benchmark (1997-2007) period.[8] The challenge is to obtain an estimate for this parameter. For this purpose I follow two methods, both of them inspired in the house price index literature. The first follows a *hedonic* approach, estimating quality using location - housing type groups. The second uses repeated sales of the same unit (matched using address).

3.1. ***House Groups***

I first use data on type of dwelling (detached, semi-detached, terrace, flat) and location to group houses and then takes mean prices within these groups as proxies for α_i. In using this information I follow the spirit of *hedonic* or spatial house price indices which control for unit characteristics to eliminate changes in the composition of sales (see Hill (2012) for a survey).

Formally, the method proceeds by estimating the following specification by OLS:

$$p_{it} = \delta_{it}^{TTWA} + \mu_j + \xi_{it}.$$

Again p_{it} corresponds to the log of price for house i sold at quarter t. Parameter μ_j is a dummy for location or location-type group j, δ_{it}^{TTWA} is a set of city specific time effects, and ξ_{it} is an error term. The set of city-by-quarter dummies in δ_{it}^{TTWA} filters out city-wide variation in prices. The

[8]The period used in the estimation of quality does not affect the qualitative results.

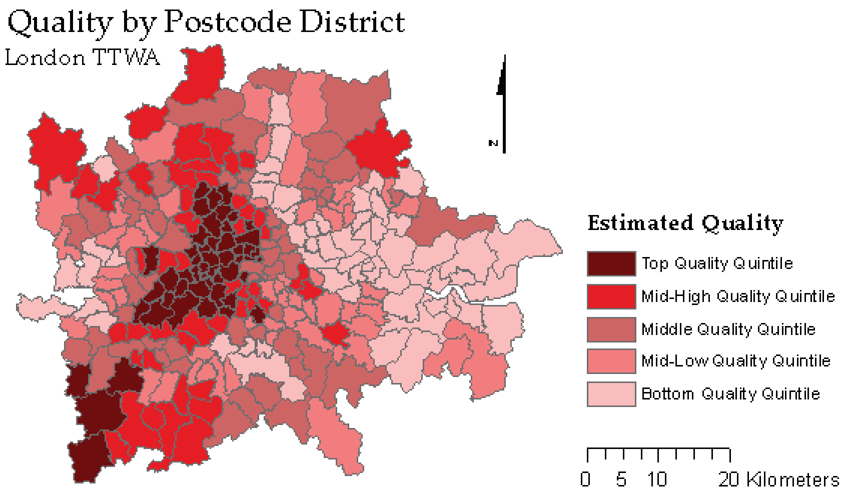
set of dummies μ_j captures price variation between dwellings *within* cities. Location and dwelling types are important determinants of housing prices and explain a large fraction (over 70%) of their cross-sectional variance. Moreover, location-dwelling type groups have stable price rankings within each TTWA. Both of these conditions make them reasonable proxies for α_i. I use $\widehat{\mu_j}$ as proxies for quality in each group *j*.

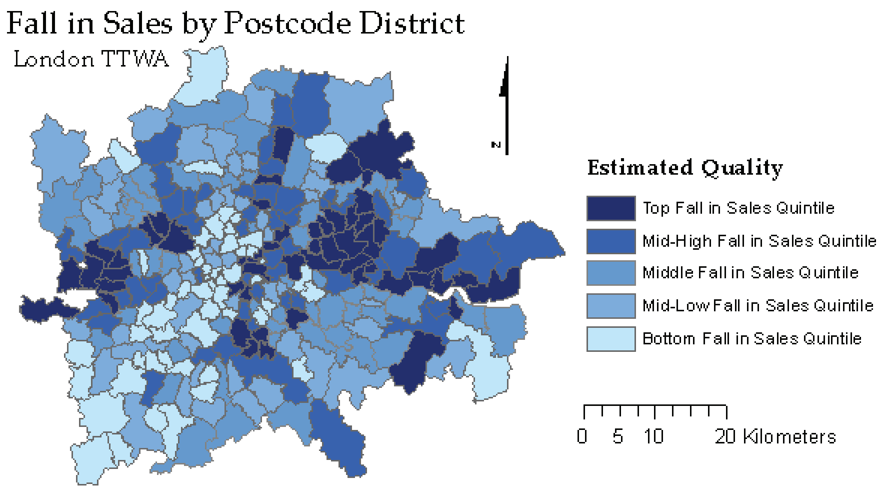
As an initial illustration, I focus on the case of the London TTWA and group houses by postcode district. There are roughly 270 postcode districts in this metropolitan area and fixed effects at this level explain 77% of the cross-sectional variance in log prices. Once I estimate $\widehat{\mu_j}$, I assign postcode districts into estimated quality quintiles. I then compare these quality quantiles to the change in transactions and house prices at the postcode district level. In both cases the change is taken over the 2007 and 2009 periods.

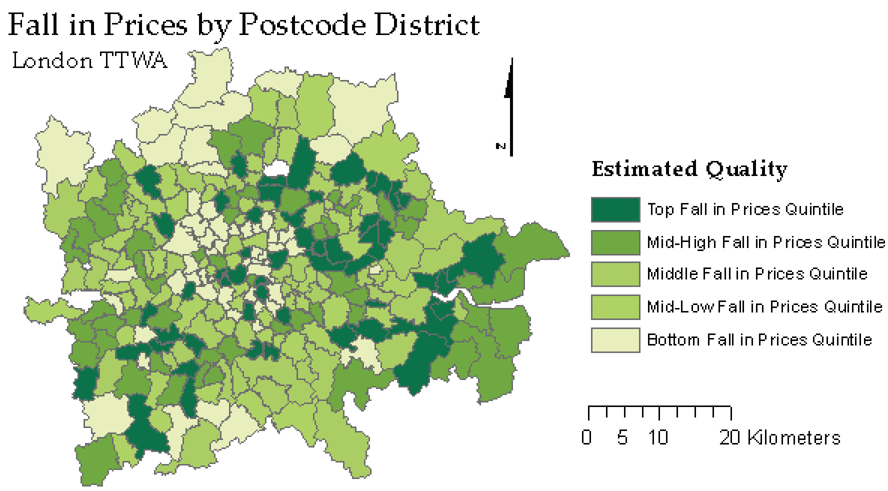
I illustrate the results in the map shown in Figure 3. The upper panel displays a map of London's postcode districts in which darker shades correspond to higher quality (more expensive) areas. We observe that central London and the South West are high quality areas whereas the East is cheaper. In the middle panel I portray the change in transactions in each district with darker shades corresponding to larger decreases in the number of sales between 2009 and 2007. Finally, the bottom panel displays the change in prices for each area with darker shades corresponding to larger declines.

The comparison between these maps is illustrative of the stylized fact documented in this paper. Comparing the top and middle panels we can observe that places with higher quality experienced more moderate reductions in transactions. Take, for example, the case of central London and the South West. In both cases we observe a corridor of high quality areas with some of the smallest declines in transaction volumes. The opposite happens in the more affordable areas in East London, which experienced a sharper reduction in sales. The picture for prices is less clear. In the third panel, we observe that several districts in the South West rank high in the distribution of price reductions.

Figure 3: Postcode Districts in London TTWA







The correlation between price drops and low quality is only clear in the east and less so than in the case of transactions.

I now turn to a detailed analysis, combining more disaggregated location data with information on dwelling types in my estimation of quality and extending the analysis beyond London. For this purpose I define groups at the postcode sector - dwelling type level. A postcode sector dwelling-type group identifies a type of house in a specific location.[9] A total of 36,085 postcode sector - dwelling type (PS-DT) groups had at least one sale during the benchmark (1997-2007) period. I now re-estimate the price equation above using this definition of groups. Parameter μ_j now corresponds to a PS-DT dummy for group j.

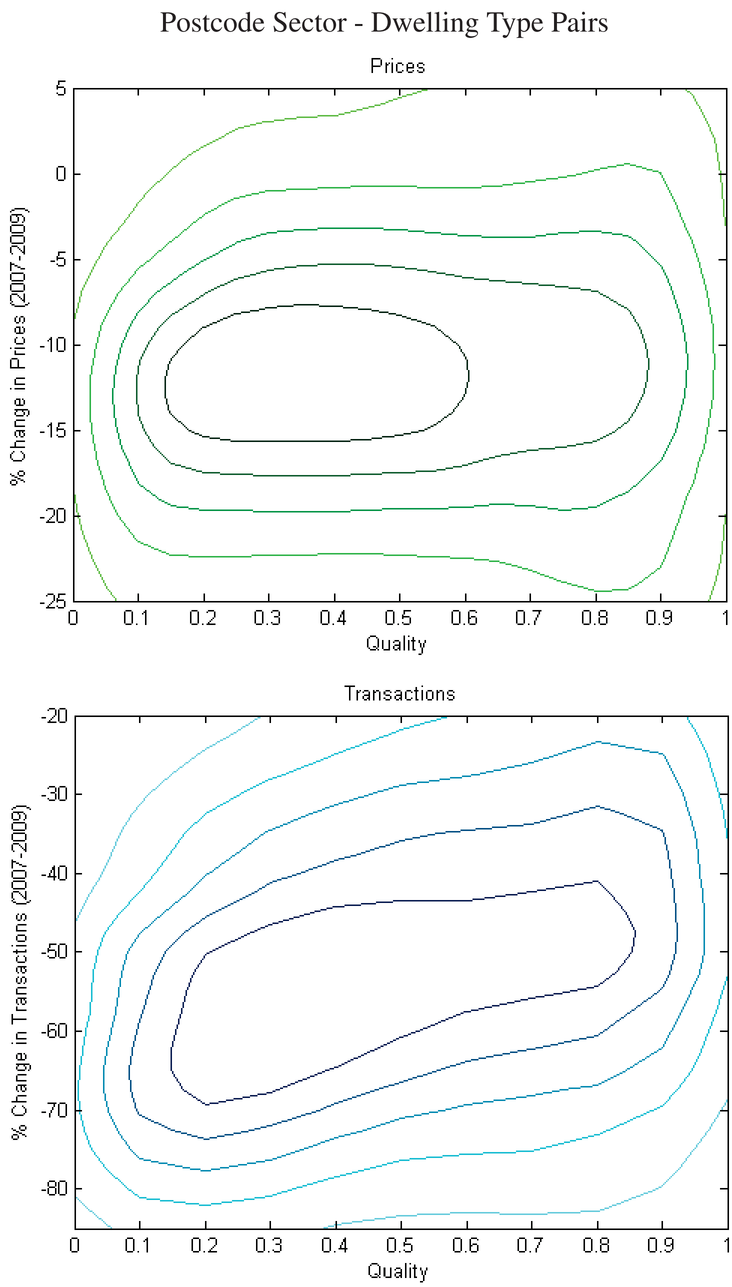
I obtain $\widehat{\mu_j}$ as proxies for quality in each group. For all PS-DT pairs having positive sales in 2007 and 2009, I compute the percent difference in mean prices between peak (2007) and trough (2009) as well as the difference in average yearly transactions between both years. Figure 4 plots these differences against the within-TTWA rank of estimated quality. The figure represents contours for a kernel density estimated over the underlying scatter plot of housing groups. Contour lines correspond to different quantiles of the estimated density.

The change in prices is shown in the top panel. We can see it was on average negative, as expected, and that it was fairly homogeneous across qualities. The correlation on the kernel density estimate appears close to 0 or slightly positive.[10] Turning to transactions, the bottom panel of Figure 4 displays a clear positive correlation: the percentage drop in transactions was lower for houses higher up in the quality distribution with the correlation being roughly 17%. The pattern is observed consistently in the vast majority of TTWAs including the 10 largest ones (not shown). The fact that the number of transactions fell more for lower quality houses implies a change in

[9]For example: detached houses in postcode sector E1 4, semi-detached houses in postcode sector WC2A 2 or detached houses in postcode sector CV4 7.

[10]In order to further explore this, I have divided houses into high and low quality by splitting them with respect to the TTWA-specific median and estimate price indexes for each of these groups. After their peak in late 2007, prices fell for both groups to their lowest level in 2009. The fall was not quite symmetric, the index for low units fell by 18% while the one for high units fell by 16%. Still, the difference is rather modest and masks substantial heterogeneity between cities.

Figure 4: Change in Prices and Transactions by Quality



Note: **Top**: plots the change in prices between 2007 and 2009 against the within-TTWA quality rank. **Bottom**: plots the change in yearly transactions between the 2007 and 2009 periods against the within-TTWA quality rank. In both cases the units are the postcode sector-dwelling type pairs with positive sales in both years. The figure plots the contour plot of an Normal kernel density estimate with bandwidth chosen according to Silverman's rule-of-thumb. Contour lines chosen using quantiles of the density estimate.

composition: the fraction of total transactions corresponding to these units was lower after 2008.

Alternatively, I estimate the change in prices and transactions for different location-type groups by estimating the following specifications using OLS and data for years 2007 and 2009 only:

$$log(\overline{price})_{jt} = \beta_1^{price} Quality_j + \beta_2^{price} Quality_j \times d_{2009} + \eta_t^{price} + \epsilon_{jt}^{price}$$

$$log(trans_{jt}) = \beta_1^{trans} Quality_j + \beta_2^{trans} Quality_j \times d_{2009} + \eta_t^{trans} + \epsilon_{jt}^{trans}$$

The dependent variables $log(\overline{price})_{jt}$ and $log(trans_{jt})$ correspond to the logarithms of the mean price and the number of transactions for group j in year t, respectively. In both cases the variables are normalized so that the relevant coefficient can be interpreted in terms of 2007 standard deviations of the dependent variable. Variable d_{2009} is a dummy taking value 1 in 2009. The coefficients of interest in this context are β_2^{price} and β_2^{trans} which measure the respective changes in the slopes of the quality-price and quality-transactions relationships.

Table 1: Stylized Fact - Quality Estimated by Groups

	(1) $log(\overline{price})$	(2) $log(\overline{price})$	(3) $log(trans)$	(4) $log(trans)$
Quality	1.082***	1.084***	-0.158***	-0.163***
	(0.0322)	(0.0339)	(0.0148)	(0.0199)
Quality $\times d_{2009}$	0.00672**	0.00302	0.110***	0.121***
	(0.00318)	(0.00581)	(0.0267)	(0.0111)
d_{2009}	-0.0233***		-0.161***	
	(0.00353)		(0.0187)	
Observations	48,442	48,442	48,442	48,442
R-squared	0.910	0.911	0.079	0.082
TTWA Effects	Yes	Yes	Yes	Yes
TTWA - Year Effects	No	Yes	No	Yes

Note: In column 1 and 2 the dependent variable is the standardized logarithm of mean prices. In columns 3 and 4 it is the standardized number of transactions. In both cases the standardization amounts to subtracting the mean and dividing by the standard deviation, both calculated within the TTWA. All columns estimated via OLS over the sample of location type groups with positive sales in both 2007 and 2009. Standard errors are clustered at the postcode district level in all cases.

Estimates for β_2^{price} and β_2^{trans} are presented in the second row of Table 1. We can see that in all cases the coefficients of interest are positive. The coefficient on the time effect d_{2009} in column 1 indicates that the price of a unit of average quality declined by a 2.3% of the cross sectional standard deviation between 2007 and 2009. The coefficient on the interaction term indicates that the decline in prices was only slightly larger for properties with quality a standard deviation below the average (-(0.023+0.006)=2.9%). Including TTWA-year effects in column 2 makes the interaction term indistinguishable from 0. In the case of transactions, we also find the coefficient on the time dummy is negative and significant, (i.e. transactions dropped for units of average quality). But the coefficient for the interaction term in column 3 indicates that properties with qualities one standard deviation below the average experienced a 2/3 larger drop in transactions than properties of average quality. Note that this result *is* robust to controlling for year-TTWA effects.

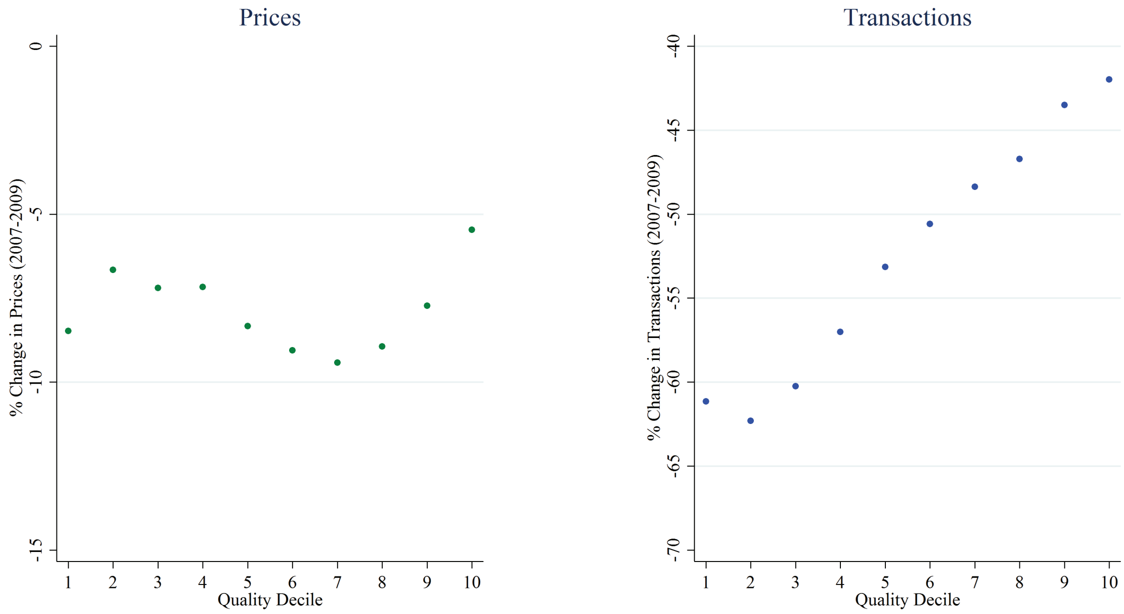
Hence, while there was only a small increase in the difference in prices between the lower and higher ends of the market in 2009, the difference in transaction volumes between between segments changed substantially. This is another expression of the stylized fact documented above. While the fall in prices between 2007 and 2009 was fairly similar for units of different quality, transactions fell much more in the lower end of the market.

3.2. ***Repeat-Sales***

The second approach used to estimate housing qualities is inspired by the *repeat-sales* method proposed initially by Bailey, Muth and Nourse (1963) and popularized after Case and Shiller (1989). For this purpose, I focus on the sub-sample of units which had been sold at least twice between 1995 and 2013. Having more than one sale allows me to estimate quality from historical selling prices at the dwelling level. To do so, I estimate $p_{it} = \pi_t^{TTWA} + \alpha_i + \xi_{it}$ by fixed effects to obtain an estimate for α_i. I next use these estimates to compute deciles of the α_i distribution for each TTWA and classify houses using these estimated deciles. Finally, I compute the change in transactions and prices for each of these groups. Results are presented in Figure 5.

The results are qualitatively the same as those obtained estimating quality using PS-DT groups.

Figure 5: Change in Prices and Transactions by Quality



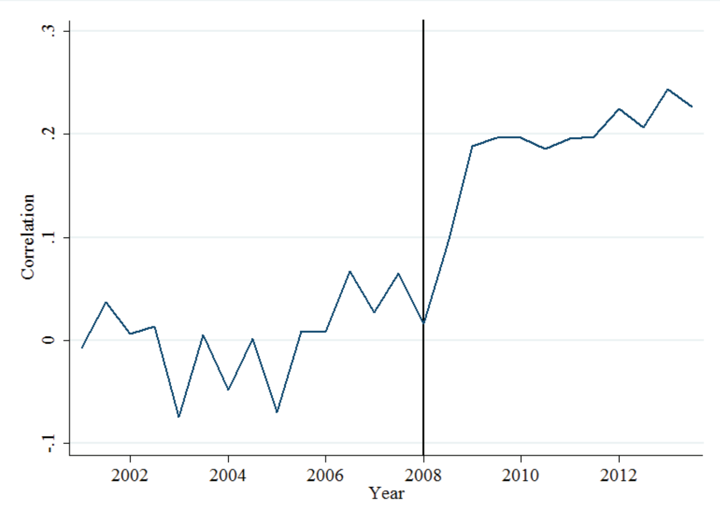
Note: **Left-panel:** Change in average prices between 2007 and 2009 (peak and trough of the aggregate price index series) for within-TTWA quality deciles. **Right-panel:** Average change in yearly transactions between 2007 and 2009 for within-TTWA quality deciles. Quality estimated at the level of individual houses in the repeat-sales sample.

The change in prices across the quality distribution (pictured on the top panel) shows no clear pattern and is fairly homogeneous, between -10% and -5% for all deciles. On the other hand, transactions (pictured on the bottom panel) fell more for relatively lower quality units (60% against 40% at the upper end of the market), confirming the change in composition discussed above. This shift is present in the overwhelming majority of TTWAs (not shown).

Both the housing group and repeat-sales methods yield similar result so I conclude that between 2007 and 2009 the drop in transaction volumes was larger at the lower end of the market. But was this change in the composition of sales specific to this period or does it happen regularly? To answer this question I construct a panel of PS-DT pairs at the quarterly frequency. For each pair I use the quality estimates described above and then calculate the correlation between quality and the number of transactions for each quarter. These correlations are plotted in Figure 6.

We can see that over the 2000-2007 period, the correlation between the quality of traded units and transactions was relatively stable around 0. Correlations increased abruptly in late 2008 and

Figure 6: Correlation between Quality and Transactions



Note: Plot of the cross-sectional correlation between estimated quality and the number of transactions for each semester between 2000 and 2013. Units are the 36,085 postcode sector - dwelling type pairs with positive sales in the 1997-2007 period.

oscillated around 0.2 thereafter. The timing of this shift largely coincides with the change in borrowing conditions in UK credit markets. Further results on the change in this correlation are presented in Figure A3, in Appendix 1. While, admittedly, this time-series evidence is not conclusive, it is consistent with the hypothesis that the stylized fact was related to the reduction in the supply of high LTV mortgages on offer by British banks during 2008.

Robustness

I have run several complementary tests to confirm the robustness of the empirical results above. First, I can show that my housing quality estimates are stable over time: a unit which has a high estimated quality over a given period is very likely to have a high estimated quality for a different period. Note that this is not necessarily the case, as units may be remodelled or upgraded, neighbourhoods may experience change in demographic composition, become gentrified or enter a phase of decay. Fortunately, the assumption that quality is (approximately) fixed can be tested. For this purpose, I compute quality estimates for the same unit in different time periods. I then check whether these estimates fall in similar quantiles of the cross-sectional quality distribution. The corresponding rank correlation plots are provided in Figure A4 of Appendix A. The quality correlations for these different periods are all comfortably above 0.9, indicating that the fixed quality assumption may be a reasonable approximation.

Next, I test whether the stylized facts reported above can be detected using a simpler definition of quality. To do so, I look at the evolution of sales and prices for different dwelling types, as recorded in the Land Registry source. I compare observed changes in volumes and prices for the highest quality type (detached dwellings) and the lowest quality type (terraced housing). Studying how these houses fared during the crisis confirms the results obtained for more refined definitions of quality. The share of total transactions of higher quality detached houses increased abruptly in 2008, while that of terraced units fell. Prices dropped for both units in the 2007-2009 period, with the decline in the price of terraced units being only slightly larger than that for detached houses (15.1% vs. 13.6 %). These results are reported in Figure A5 of Appendix A.

Finally, I report that the findings above are robust to the inclusion of leaseholds and new-builds in the analysis. When using this extended sample to detect changes in the composition of sales, the qualitative picture is very similar: average yearly transactions after 2008 fell more for relatively lower quality housing. This result is documented in Figure A6 of Appendix A.

I conclude that the stylized facts reported in this section are robust to some key methodological choices on how to measure quality or transaction volumes. The next section investigates the economic origin of these facts.

4. Credit Conditions and the Composition of Sales: Direct Evidence

A large and arguably unexpected change in credit conditions affected British housing markets in 2008, when banks removed high LTV mortgages from offer in the midst of the Great Recession. Trends in UK mortgage markets around this year can be observed in Figure 7, which was constructed using data from Nationwide mortgages to first-time buyers.[11] The left panel shows that, before 2008, the typical FTB could buy a house by paying a deposit of 10% of the total value and obtaining a loan on the remaining 90%. With the advent of the financial crisis, median LTVs for this group decreased abruptly from 90% in early 2007 to roughly 75% by 2009. This change in median coincided with a broader change in the whole distribution of LTVs. The right panel of Figure 7, shows how the cumulative distribution of mortgage LTVs to first-time buyers changed between 2005 and 2011. We can see that much of the mass of the distribution shifted to the left. By 2009, LTVs above 90% had become a negligible fraction of total loans. The change in LTV ratios implies increased down-payment requirements became necessary for prospective FTBs.[12] Survey evidence from British banks indicates this change in credit conditions was largely supply driven.[13]

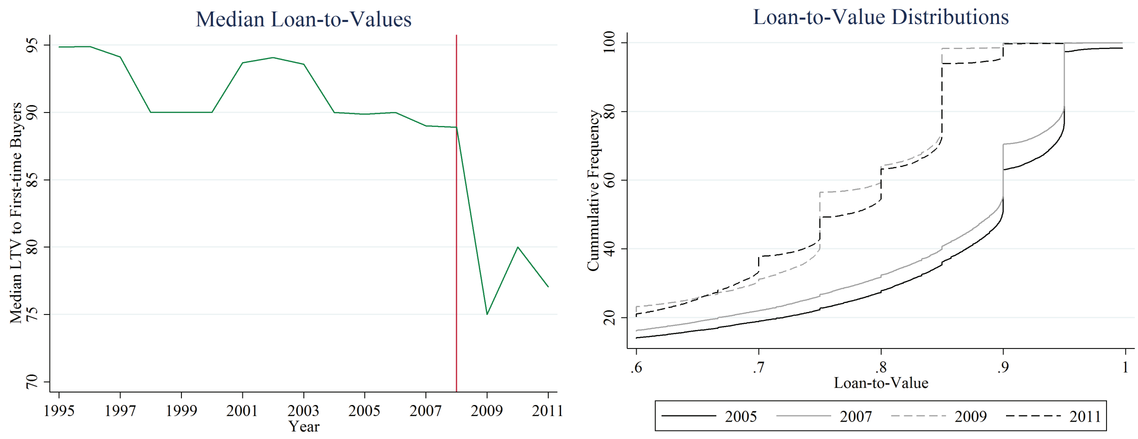
This section tests whether this change in credit conditions affected the composition of sales. The fact that this was an aggregate shock complicates the empirical analysis because all areas of the country were affected by this change in lending. However, while the removal of high LTV mortgages from offer occurred at the national level, its effects are likely to be heterogeneous across markets. Relatively unaffordable markets, where first-time buyers typically purchase houses using high LTV mortgages, experienced a sharper tightening of credit conditions than markets where LTV were initially low to begin with. This provides cross-sectional variation in the change in credit conditions across markets and motivates the empirical strategy employed. The intuition is that the size of the shock is larger in cities where households typically needed high LTV loans to become

[11] Very similar patterns are observed using data from the Council of Mortgage Lenders on all mortgage providers. See Figure A8 in appendix A.

[12] Evidence from the Wealth and Assets Survey and the Survey of Building Society Mortgages show that first-time-buyers are the group taking up the largest LTV mortgages. This is the case because they have lower accumulated wealth and hence are less capable of paying large deposits.

[13] The Bank of England's Credit Conditions Survey records lending availability and borrowing conditions as reported by British banks. Survey responses indicates i) there was a substantial reduction in credit availability for secured lending between the last quarter of 2007 and the first of 2009; ii) Maximum Loan-to-Value mortgages offered by British banks also decreased during this period; iii) there was a substantial tightening of the criteria used to approve borrowers for secured lending, coupled with a substantial reduction in the percentage loan requests being approved; and iv) the reduction in credit availability was almost entirely concentrated on high LTV mortgages (over 75%). Figures in support of each of these points are presented in Appendix A (Figure A9).

Figure 7: Loan-to-Value Ratios - Nationwide Mortgages



Note: **Left:** Evolution of median Loan-to-Value ratio on mortgages granted to first-time buyers by Nationwide (in percentage terms). **Right:** Cumulative distributions of LTVs for First Time Buyers for years 2005, 2007, 2009 and 2011 in the Nationwide dataset.

home-owners.

I build a lower super output area (LSOA) level panel covering 2007 and 2009 and use it to estimate the effect of the change in credit conditions on sale volumes using specification 1:

$$\Delta log(trans)_{i2009} = \beta_1 \Delta LTV_{j2009} + \beta_2 \Delta LTV_{j2009} \times Quality_i + \beta_3 Quality_i + \phi \Delta X_{i2009} + \Delta \epsilon_{i2009} \quad (1)$$

where $log(trans)_{it}$ is the natural logarithm of the number transactions in LSOA i in time t with $t = \{2007, 2009\}$, α_i is an LSOA fixed effect, LTV_{jt} is the average Loan-to-Value ratio of first-time buyer mortgages in city j and period t (measured in percentage points), $Quality_i$ is the LSOA specific housing quality, estimated as in section 3.1 and normalized to have mean zero and standard deviation 1, X_{it} is a set of city and area specific controls, and ϵ_{it} is an error term.[14] Time differencing, indicated by Δ, is taken between 2009 and 2007. The set of controls include the city-level unemployment, employment, participation and youth unemployment rates as well as the fraction of

[14] We can see this specification as a differenced version of the equation in levels:

$$log(trans)_{it} = \alpha_i + \beta_1 LTV_{jt} + \beta_2 LTV_{jt} \times Quality_i + \beta_3 Quality_i \times d_{2009} + \delta d_{2009} + \phi X_{it} + \epsilon_{it}$$

Note that d_{2009} is a fixed effect for observations recorded in 2009. Given that we are using a two period panel, the within-groups and first-difference estimator coincide.

workers in professional occupations, obtained from the Annual Population Survey. I also include the fraction of jobseeker's benefit claimants, at the LSOA-level, and mean and median wages.[15] Under the assumption of strict exogeneity of ΔLTV_{j2009} and $\Delta LTV_{j2009} \times Quality_i$, β_1 measures the effect of *LTV* on transaction volumes and β_2 measures the differential impact of credit conditions across segments of the housing market. β_3 captures whether different segments experienced different changes in transactions between 2007 and 2009 for other reasons.

Results for OLS estimation of 19 are presented in Columns 1 and 2 of Table 2. Column 1 presents results without controls, while column 2 includes both city level and area level controls. In the first place, we can observe that in both columns the effect of credit conditions on transaction volumes is small and not significantly different from 0. This means that the effect of credit tightening on transactions of houses of average quality is negligible. Our main coefficient of interest is the one corresponding to $\Delta LTV_{j2009} \times Quality_i$, which is negative and significant. Because the quality variable is standardized, this indicates that changes in credit conditions will have different effects on the upper and lower segments of the housing market. For units with quality 1 s.d. below the mean, a 1 percentage point drop in LTVs reduced transactions by roughly 1 percent (0.7% in column 2). Taking a 10% drop as an approximation for the average change in LTVs, this would roughly translate into a 10 percentage point larger drop in transactions at the low end of the market.

The strict exogeneity assumption needed to give causal interpretation to the OLS estimates in Table 2 is strong. There may be three sources of endogeneity at play. In the first place, reverse causality could exist if banks change their lending criteria in response to other shocks to housing markets. This issue is especially important if we take into account that transaction volumes are known to be a leading indicator of housing market performance (see Miller and Sklarz (1986), De Wit, Englund and Francke (2013)). A second problem may arise due to measurement error.

[15] I use data at the most disaggregated level available. Descriptive Statistics for the city level variables are presented in table A2, in Appendix A.

Table 2: Change in Loan-to-Value and Transactions (OLS & IV)

	OLS		IV (ltv_t-1)		IV (ltv_1999)		IV (both)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ LTV × Quality	-0.010**	-0.007**	-0.018***	-0.009**	-0.046***	-0.010**	-0.009**
	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
Δ LTV	-0.001	-0.001	0.012**		-0.010		
	(0.00)	(0.00)	(0.00)		(0.03)		
Quality	0.183***	0.133***	0.129***	0.181***	0.149***	0.181***	0.181***
	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
Δ Job Seekers		-12.892***	-12.428***	-8.193***	-10.916***	-8.161***	-8.201***
		(0.73)	(0.82)	(0.97)	(0.95)	(0.97)	(0.97)
Δ Unemp.		-0.025***	-0.019**	-0.012	-0.025	-0.012	-0.012
		(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
F-stat 1	-	-	68	-	17	-	-
F-stat 2	-	-	47	46	33	35	47
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes
TTWA Effects	No	No	No	Yes	No	Yes	Yes
R^2	0.12	0.14	0.13	0.20	0.10	0.20	0.20
Observations	33573	33572	33572	33572	33555	33555	33555

Notes: LSOA (Census-area) level regressions. Dependent Variable in all columns is the difference in the logarithm of transactions in a census area between 2007 and 2009. Columns 1 and 2 report OLS estimates for coefficients in equation 1. Columns 3 an 4 correspond to IV estimates using the initial (2007) average LTV to first-time buyers as an instrument. Columns 5 and 6 use this average for 1999. Column 7 combines both instruments. The list of controls is reported in the text. Only the coefficients for the change in claimants for the job seeker allowance and changes in unemployment reported in the table. F-statistics for first-stage regressions included as indicated in the table.
* p < 0.1, ** p < 0.05, *** p < 0.01.

The ΔLTV_{j2009} measure used here is based on data for a sample of mortgages from one lender only. While the data is quite representative of total sales (see Figure A7 in Appendix A), LTV averages will contain some degree of measurement error and this could bias coefficients towards zero. Finally, local economic shocks associated to the Great Recession could affect credit and labour markets to produce a drop in LTVs and sales (for example due to changing incomes for the young, a channel emphasized for example in Muellbauer and Murphy (1997) and Ortalo-Magne and Rady (1999)). While controls are included to help deal with some of these confounders, it is likely that part of the shock operates via unobservable channels.

I propose two alternative solutions to this problem. The first is to use pre-crisis measures of LTVs to first-time buyers as instruments for ΔLTV_{j2009}. The second is to include travel-to-work area fixed effects to account for city wide shocks.

If we relax the strict exogeneity assumption invoked above and instead assume that variable LTV_{jt} is predetermined, we can allow for contemporaneous correlation between this variable and the error term (see Arellano (2003)). Under this assumption, $E(LTV_{j2007}\epsilon_{j2009}) = 0$, and I can use LTV_{j2007} as an instrument for ΔLTV_{j2009} in estimating equation 1. Moreover, given that $Quality_i$ is fixed, we can construct an additional instrument $LTV_{j2007}Quality_i$ for the interaction term. One issue with this instrument is that cross-sectional variation in lending conditions at the onset of the crisis are themselves related to changes in risk taking behaviour by banks during the pre-crisis boom.[16] In order to avoid this problem, I consider an alternative, LTV_{1999}, which measures average LTVs in loans to first-time buyers at the TTWA level in 1999. This will still be related to affordability in English cities (and to the need of high LTV mortgages by FTBs) but not to changes in credit conditions in the run-up to the crisis. The relevance condition for these instruments is satisfied as can be seen in the F-statistics reported in Table 2.

Results for the IV estimation of equation 1 using instruments LTV_{2007} and LTV_{1999} are provided in columns 3 and 5 of Table 2, respectively. For both instruments, we observe that the coefficient on $\Delta LTV \times Quality$ is negative and significant. The coefficient on ΔLTV is significant and has the expected sign in the case of the first instrument, but is not significantly different from 0 when instrumenting with LTV_{1999}. I can use these coefficients to calculate the effect of a change in LTVs on sales of properties with qualities 1 s.d. below the mean. In the case of column 3, the combined effect of a percentage point reduction in LTVs on these properties would be a 3% reduction in transactions (0.0125-(-0.0181)=3.06%) and is significant at all conventional levels. For column 5, the same effect would be 4.62%. These are large effects, which could account for much of the observed heterogeneity in the evolution of sales between 2007 and 2009. The coefficients are larger than those for OLS, perhaps due to the fact that IV estimates are less likely to be rigged with measurement error. I conclude from these results that credit tightening had a substantial impact on the reduction of transaction volumes at the lower end of the market.

[16]This would be the case especially if there was a substantial expansion of credit in the United Kingdom in the 2000-2007 period. While this is certainly the case in the United States – and did affect subsequent market outcomes (Mian and Sufi (2009)) – lending conditions had been relatively lax in England and Wales for some time. See left panel of Figure 7.

The assumptions required to give causal interpretation to the IV estimates in Table 2 are still relatively strong and deserve further discussion. If markets with initially high LTV ratios experienced large negative economic shocks in 2008-2009, these assumptions would be violated. To test whether this is the case, I run a series of balancing checks by estimating univariate regressions of the instruments on city-level variables measuring changes in economic conditions. Estimates from these regressions are reported in Table 3. We observe that in all but one case there is no statistically significant relationship between the instruments and the covariates, which is reassuring. I do find a significant partial correlation between the IVs and the fraction of population receiving the job-seeker allowance. Recall I have included this fraction as a control in all specifications.

Table 3: Balancing Tests

	D. Unemp	D. Employ	D. Inactive	D. SelfEmp	D. Profess
LTV_{t-1}	0.0303	-0.0116	-0.00580	-0.0397	0.0248
	(0.02)	(0.05)	(0.05)	(0.03)	(0.04)
Observations	186	186	186	186	185
	D. High Edu	D. YouthUnemp	D. Seekers	D. Mean W	D. Median W
LTV_{t-1}	0.0459	-0.00980	0.0191***	0.300	0.440
	(0.07)	(0.04)	(0.00)	(0.64)	(0.44)
Observations	186	186	186	186	186
	D. Unemp	D. Employ	D. Inactive	D. SelfEmp	D. Profess
LTV_{1999}	0.0504	0.0775	-0.154*	-0.0484	-0.00418
	(0.03)	(0.10)	(0.08)	(0.04)	(0.04)
Observations	185	185	185	185	184
	D. High Edu	D. YouthUnemp	D. Seekers	D. Mean W	D. Median W
LTV_{1999}	0.0287	-0.00183	0.0297***	0.540	0.868
	(0.08)	(0.06)	(0.01)	(0.83)	(0.64)
Observations	185	185	185	185	185

Notes: Balancing checks for the instrumental variables used in this section. TTWA level regressions in all specifications suing univariate regressions of selected controls on the instruments. Robust standard errors in parenthesis. 186 TTWAs in total (1 missing LTV data in 1999).

Perhaps some remaining unobserved variation in city-level economic performance could still be correlated with the instruments. In order to further explore this, I modify equation 19 to include interaction terms $\Delta X_{i2009} \times Quality$. Coefficient estimates for these interacted controls can indicate whether business cycle shocks have a differential effect on transactions across segments of the housing market and threaten instrument validity through this channel. Estimates and joint significance test statistics are provided in Table A3 in Appendix B. Almost all of the coefficients on these interaction terms are insignificant. Importantly, they are jointly insignificant at all conventional levels. I interpret these estimates as indicating that economic performance did not have a substantial heterogeneous effect on the change in transaction volumes.

I also re-estimate equation 19 including TTWA fixed effects. These will account for any city level shocks over the 2007 – 2009 period. Variable Δ LTV will be subsumed by these fixed effects, but we can still estimate the differential effect of credit tightening on transactions for different segments of the housing market. Results are provided in columns 4 and 6 of Table 2. I obtain very similar coefficients on variable $\Delta LTV \times Quality$ in both columns. Column 4 indicates that for properties with a quality 1 standard deviation below the mean, a 1 percent reduction in LTV ratios leads to a 0.9% reduction in transaction volumes. In the case of column 6, this effect is 1%. We can also combine both instruments in one specification, as reported in column 7. The effect is now 0.9%.[17] Note that the resulting coefficients are now quite close to those obtained under OLS.

Thus far this section has discussed the link between credit conditions and transaction volumes, I now briefly turn my attention to the case of housing prices. I re-estimate equation 19, but now using $\Delta price_{j2009}$ as the dependent variable. In this way, I try to capture whether credit conditions had a differential effect on prices across different segments of the housing market. OLS and IV estimates for these coefficients are provided in Table 4. Results are consistent with the descriptive patterns observed in section 3. There is no evidence that relative prices of low quality housing decreased in places which experienced a sharper tightening in credit.

[17] The over-identification test in this specification does not reject the null of valid instruments with a p-value of 0.58.

Table 4: Change in Loan-to-Value and Prices (OLS & IV)

	OLS	IV (ltv_t-1)		IV (ltv_1999)		IV (both)
	(1)	(2)	(3)	(4)	(5)	(6)
Δ LTV $\times$ Quality	0.0002	0.0002	0.0001	0.0016	0.0004	0.0002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ LTV	-0.0002	-0.0011*		-0.0010		
	(0.00)	(0.00)		(0.00)		
Quality	0.0105***	0.0110***	0.0134***	0.0106***	0.0134***	0.0134***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δ Job Seekers	-1.0012***	-0.9971***	-0.7069**	-1.0553***	-0.7138**	-0.7068**
	(0.31)	(0.31)	(0.32)	(0.33)	(0.33)	(0.32)
Δ Unemp.	-0.0060***	-0.0064***	-0.0058**	-0.0064***	-0.0059**	-0.0058**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
F-stat 1	-	68	-	17	-	-
F-stat 2	-	47	46	33	35	47
Controls	Yes	Yes	Yes	Yes	Yes	Yes
TTWA Effects	No	No	Yes	No	Yes	Yes
R^2	0.01	0.01	0.02	0.01	0.02	0.02
Observations	33572	33572	33572	33555	33555	33555

Notes: LSOA (Census-area) level regressions. Dependent variable in all columns is the difference in the logarithm of average prices in a census area (cross sectional unit) between 2007 and 2009. Columns 1 and 2 report OLS estimates for coefficients in equation 1. Columns 3 an 4 correspond to IV estimates using the initial (2007) average LTV to first-time buyers as an instrument. Columns 5 and 6 use this measure for 1999. Column 7 combines both instruments. List of controls as highlighted in the text. Only the coefficients for the change in claimants for the job seeker allowance and changes in unemployment reported in the Table.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5. Model

I now present a deterministic overlapping generations framework in which credit conditions affect the composition of housing transactions. As in Ortalo-Magne and Rady (2004) and Ortalo-Magne and Rady (2006), the model features heterogeneity both in dwelling types and household incomes, and transactions are intergenerational transfers of houses. In my framework, older, wealthier households can become landlords of starter units and therefore compete for ownership with the young households. Some of these young households become renters and are effectively priced out of home-ownership. Affordability for younger households will be determined by credit conditions. With abundant credit, young households have more available resources to compete for ownership. Tighter credit will benefit wealth-rich landlords.

I first show analytically that steady states (SS) with tighter credit constraints have a relatively smaller fraction of sales in the lower side of the market and a larger fraction of households living as renters. Importantly, changes in the composition of transactions arise because of changes in the number of units that are retained and rented out by wealthy households when moving up the housing ladder. In this way, I emphasize the role of let-to-buy (moving up without selling the starter home) in affecting housing sale volumes and the inter-generational competition for ownership.[18] Depending on parameter values, the model can accommodate several different lifetime tenure transitions. I study steady state equilibria in which younger, poorer agents are renters and older, richer agents are landlords residing in high quality housing. I show credit tightening affects the composition of sales for these steady state allocations.

In order to explore transition dynamics in response to a permanent, unexpected shock to credit conditions, I solve the model numerically for different sets of parameters. Convergence to the new steady state can take several periods, as prices and wealth levels are jointly and dynamically determined. I show that the model can feature transitions in which the short run impact of the credit shock coincides, qualitatively, with the prediction obtained from a steady state comparison.

The model will yield a set of additional testable hypotheses at the micro level which will be tested separately in section 6.

5.1. ***Setup***

Incomes

Consider an overlapping generations economy with no uncertainty in which agents live for three periods. Agents are born without wealth but are heterogeneous in their incomes. At ages $a = 1, 2, 3$ agents of type $i \in [0, 1]$ receive an endowment $e_a(i)$ where the functions $e_a : [0, 1] \to \mathbb{R}^+$ are continuous and strictly increasing. We can think of these functions as the inverse cdf of incomes for each age cohort. I assume that $e_{a+1}(i) > e_a(i) \, \forall i$. To save on notation, I define function $e(i)$ corresponding to the accumulated lifetime endowments on period 2, if all period 1 income is saved

[18] The term *let-to-buy* is used in the United Kingdom to refer to transitions in which a household trades up the ladder and rents out the unit where they resided when young. Not to be confused with *buy-to-let*, which is associated to expressly buying a unit to rent it out.

at interest rate r (i.e. $e(i) \equiv e_1(i)(1+r) + e_2(i)$). Note that function $e(i)$ is again continuous and strictly increasing.

Housing Stock & Ownership

There is a fixed stock of housing units $\overline{S} = S_L + S_H$ with S_L and S_H being the stock of low and high type dwellings respectively. I assume $\overline{S} < 2$ which ensures positive rental prices. I also assume $S_L > 1$ and $S_H > 1/2$. The housing stock owned by an agent of age a and type i at the beginning of period t is given by vector $h_t(i, a) = (h_{L,t}, h_{H,t})\prime$. Scalars $h_{L,t}$ and $h_{H,t}$ record the number of type L and H properties owned by the agent, respectively. Households can own more than one dwelling and rent it out in exchange for rental income. Prices for low and high houses in period t are $p_{L,t}$ and $p_{H,t}$, respectively. Alternatively, agents can rent a house by paying R_t. Rents are paid in advance. These prices are determined endogenously in the model.

Preferences

Households have preferences over housing and a numeraire consumption good. Their per period utility function is given by $U(c_t, h_t) = c_t + u_h(\tau_t)$, where c_t indicates consumption of the numeraire and τ_t indicates residential choice at the beginning of the period. Utility from housing depends on consumption c_t and housing tenure $\tau_t = (\tau_{R,t}, \tau_{L,t}, \tau_{H,t})\prime$ with the elements of vector τ taking value 1 depending on the type of residence (rental, home-ownership of an L or an H unit). The contribution of housing to individual utility is given by function $u_h(\tau_t)$ taking values:

$$u_h(\tau_t) = \begin{cases} 0 \text{ if live with parents / social housing } (\tau_t = 0) \\ \mu v_L \text{ if renting } L \ (\tau_{R,t} = 1) \\ v_L \text{ if owner occupier } L \ (\tau_{L,t} = 1) \\ v_H \text{ if owner occupier } H \ (\tau_{H,t} = 1) \end{cases}$$

Some agents may not be able to obtain access to a dwelling through the private market. We can think of these agents as residing in social housing or living with their parents, which provide minimal housing services at a price equal to the agent's current income.[19] They receive 0 utility from these housing services. Agents renting low or high type units receive utility μv_L.[20] Owner occupiers receive utilities v_L and v_H, respectively. Note that $\mu < 1$ indicates utility from renting is lower than utility from owner-occupation. Housing ownership h_t and tenure τ_t will be tightly related, as only agents owning a unit can be owner-occupiers.

Agents discount future utility at rate β. The interest rate on borrowing and saving is r. I will assume $\beta(1+r) \geq 1$. Combined with linearity of consumption in the utility function, this ensures we can assume without loss of generality that all consumption takes place in the last period. This feature is drawn from Ortalo-Magne and Rady (2006) and allows us to focus on the role of credit conditions on determining housing market decisions.

Borrowing Constraints

Collateralized borrowing is available to households. Credit constraints enter the model via a minimum down-payment requirement. Agents can borrow up to $\gamma p_{j,t}$ when buying a type j unit in period t and therefore have to pay a down-payment equal to $p_{j,t}(1-\gamma)$. We can see γ as the maximum available LTV ratio on mortgages. Importantly, agents can only have a mortgage on one of their housing units so that mortgage debt does not scale with the number of dwellings owned. This assumption plays an important role in Proposition 1. I further assume $r < min\{\gamma, 1-\gamma\}$. Combined with the assumption of increasing incomes by age, this ensures all households that take on debt can pay interest on this debt in steady state. There is no default on debt.

[19]The fact that some agents do not have access to property via the private market is a necessary consequence of the assumption that $\overline{S} < 2$. Agents are assumed to pay off their income as social rent (or transfer to parents) to ensure next period wealth is still monotonous in i.

[20]The fact that rental utility is invariant with housing type explains why there is only one rental price R_t.

Supply of Rented Dwellings

Rental supply is comprised of households owning more than one dwelling and renting these out as landlords. Define $\lambda_t(i, a)$ as the number of properties rented out by an agent of age a and type i at the beginning of period t. By assumption, deep-pocketed investors do not participate in real estate markets. As a result, the typical no-arbitrage condition is not met and the present discounted value of rental income can be *different* from the price of low type housing in equilibrium, which allows $p_{L,t}$ and R_t to evolve independently.[21] Together with the lower utility resulting from renting, this assumption is critical to ensure that credit constraints have an impact on prices and transactions.

Timing

Timing is as follows. Within each period agents first derive housing utility, they receive their corresponding endowment $e_a(i)$, pay interests on debt, receive interest from savings, trade in the low-type housing market, trade in the high-type housing market and, finally, derive utility from consumption of the numeraire good. Because agents only enjoy housing utility at the beginning of the period (and they are born with no housing wealth) the maximum possible demand for housing is equal to 2: demand from age 1 and age 2 agents. I will sometimes refer to these two groups as young (age 1) and old (age 2) agents.

Choice Variables, State Variables and Inter-temporal Decisions

Every period, agents decide whether to buy units, whether to become landlords and where to reside at the beginning of the next period, as well as whether to consume or save. Hence, in principle they choose $c_t, h_{t+1}, \tau_{t+1}, \lambda_{t+1}$. However, this can be simplified substantially. Households owning more than one property will always rent out additional properties to obtain R_t if $R_t \geq 0$. Hence, the choice of λ_{t+1} is given directly by h_{t+1}. Formally, $\lambda_{t+1}(i, a) = \sum h_{L,t+1}(i, a) + h_{H,t+1}(i, a) - 1$

[21]This will mean that nothing guarantees $r\, p_{L,t} \neq R$ in equilibrium. While the absence of institutional investors in the model may seem puzzling, recent reports on the matter indicate the UK market for private rented dwellings is dominated by small investors (see Montague and collaborators (2012)).

if $h_{L,t+1}(i,a) + h_{H,t+1}(i,a) > 0$ and 0 otherwise. Moreover, given h_{t+1}, some aspects of residential choice are known because the first home is always owner-occupied (if v_H and v_L are sufficiently high). Finally, as discussed above, all consumption takes place in the last period of households' lives so all resources not used in housing markets are saved by agents of ages 1 and 2. As a result, decisions over h_{t+1} and τ_t are sufficient to characterize all household choices.

The state variables for this economy will be the amounts of non-housing net wealth and housing wealth for every agent at the beginning of period t. Non-housing net wealth is recorded as $b(i,a)$ and maps agents' type and age to the real line. In the case of housing wealth $h(i,a)$, this will be a function from agent's type and age to the set of feasible ownership combinations. In this context, agents' value functions at age a are:

$$V^a(b,h) = \max_{\tau\prime,h\prime} c + u_h(\tau) + \beta V^{a+1}(b\prime, h\prime)$$

Policy functions $\tau'(i,x,a)$ and $h'(i,x,a)$, map the state of the economy (x) and the household type and age to their optimal decisions. Agents can only choose the housing services they will enjoy at the beginning of the *next* period.

The law of motion for individual non-housing wealth at the beginning of a period is:

$$b\prime = (1+r)(e_a(i)(1 - 1\{\tau' = 0\}) + b - c - P^{own}(h\prime - h) + R(\lambda - \tau_R)) \tag{2}$$

where τ_R takes value 1 if the agent lived in rented accommodation in period t and $\lambda\prime$ indicates the number of properties rented out as a landlord in that period. A full description of the value functions in each period, as well as a definition of the recursive equilibrium is provided in appendix B.

Equilibrium

Housing market equilibrium is a set of prices $P_t = (R_t, p_{L,t}, p_{H,t})$, gross savings $b_t(i,a)$ and housing allocations $h_t(i,a)$ in the age-type space $[0,1] \times \{1,2\}$, as well as residential decisions

$\tau_t(i,a)$, such that households make optimal choices given their budget and credit constraints, and housing markets clear. Housing market clearing is given by:

$$D_1^L(P_t) + D_2^L(P_t) + S^R(P_t) = S_L$$
$$D_1^H(P_t) + D_1^H(P_t) = S_H$$
$$D_1^R(P_t) + D_2^R(P_t) = S^R(P_t)$$

Where D_a^h is the demand of h tenure (Rented, Low-type home-owner, High-type home-owner) by age a agents buying or renting that period and S^R is the supply of rented dwellings.

Parameter Conditions

I will impose a set of parameter conditions to ensure that credit constraints are binding for all households (i.e. incentives to become a home-owner/landlord are always present). I will also impose a series of additional conditions to ensure the steady state equilibrium includes lifetime transitions following a housing ladder, where old potential landlords can outbid prospective young buyers for ownership of low type housing.

The conditions imposed on preference parameters are the following:

$$v_H > v_L > \frac{r}{1-\gamma} e(1) \tag{3.1}$$

$$\mu v_L > e_1(2 - S_L - S_H) \tag{3.2}$$

$$(1+\mu) v_L > v_H \tag{3.3}$$

$$v_H - v_L > \frac{r}{1-\gamma}(e(1) - e_1(2 - S_L - S_H)) \tag{3.4}$$

$$e_1(2 - S_L - S_H) > r e_1(1)(1-\gamma)^{-1} \tag{3.5}$$

These conditions ensure that owner occupation is always worth the user cost of housing (3.1), that renting is always worth the rental price (3.2), that households will not downsize housing consumption today to ensure better quality housing consumption in the future (3.3), that higher quality housing consumption is guaranteed to be worth the user cost in equilibrium (3.4), and that it is profitable to become a landowner of a type L unit (3.5).

Additional conditions are imposed on other model parameters including conditions on the distribution of incomes by age. These are required to restrict steady state allocations to those displaying a ladder structure:

$$e_2(0) > e_1(2 - S_L - S_H) \tag{4.1}$$

$$e_1(1) < e(1 - S_H) - e_1(2 - S_L - S_H) \tag{4.2}$$

$$e(S_H) - e(1 - S_H) > \frac{e_1(1 - S_H)}{1 - \gamma} - e_1(2 - S_L - S_H) \tag{4.3}$$

$$e(1) < e(1 - S_H) + \frac{2 + r}{1 - \gamma} e_1(1 - S_H) - (2 + r)e_1(2 - S_L - S_H) \tag{4.4}$$

$$\frac{2 - \gamma}{1 - \gamma} e_1(2 - S_L - S_H) > e(1 - S_H) \tag{4.5}$$

These conditions ensure that only young agents priced out of the private market (4.1), that only old agents reside in type H properties (4.2), that rental markets exist and marginal owners of H units were renters when young (4.3), and that no landlords rent out two properties (4.4 and 4.5).[22]

I formally lay out the link between these statements and assumptions 3.1 to 4.5 in Appendix B.

5.2. *Steady State*

Price Bounds

Under these assumptions, feasibility of housing choices will be determined by credit constraints and prices. We can use these constraints to obtain bounds on prices for H and L type units. We can also use household income directly to pin down the rental price when rental markets exist. These

[22] A simple example of housing stock, credit constraints and interest that would satisfy these conditions would be $S_H = 0.85$, $2 - S_H - S_L = 0.05$, $r = 0.01$, $\gamma = 0.8$ for uniform income distributions $e_1(i) \sim U[2, 4]$ and $e_2(i) \sim U[2.5, 15]$.

yield price bounds:

$$p_H \leq e(1 - S_H)(1 - \gamma)^{-1} \tag{5.1}$$

$$p_L \geq e_1(2 - S_L - S_H)\,(1 - \gamma)^{-1} \tag{5.2}$$

$$R = e_1(2 - S_L - S_H) \quad \text{if rental markets exist} \tag{5.3}$$

Proofs for these statements are provided in the theoretical appendix. Intuitively, the first statement follows from the fact that otherwise p_H would be so high that the richest S_H mass of agents in the economy cannot afford an H unit and markets cannot clear. Statement 5.2 follows from the fact that if p_L was lower than this level, more than $S_H + S_L$ households will be able to afford a unit. The condition on rents is also determined by market clearing condition in residential markets.

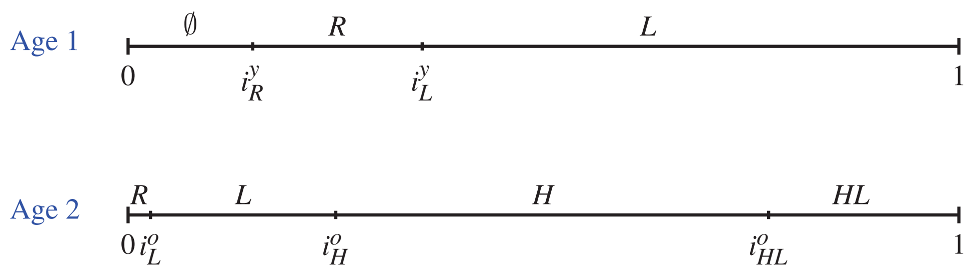
Allocations

Thresholds in the type distribution of households at every age will determine the steady state mass of homeless agents, demands for renting, owner-occupation of L units, owner-occupation of H units, and rental supply. Notation is as follows: i_R^y and i_L^y are the thresholds beyond which young agents can afford to rent and to buy a low dwelling, respectively. Likewise, i_H^o and i_{HL}^o are the thresholds above which agents can afford owning a low type dwelling, a high type dwelling or owning both a high and a low unit at the end of period 2 (landlords), respectively.[23]

Most of these thresholds are derived from credit constraints. Let us take threshold i_L^y as an example. This will be the threshold in the type distribution such that young households can barely afford a down-payment on an L unit ($p_L(1 - \gamma)$). Hence, $i_L^y = e_1^{-1}(P_L(1 - \gamma)$. The case of the marginal renters depends directly on having sufficient income to afford a rent, but is otherwise similar. Expressions for all thresholds can be found in Appendix B.

[23] Sub-indices for each threshold are as follows. Sub-index R corresponds to thresholds for rental affordability (agents to the right of the threshold can rent), L corresponds to owner-occupation of a low type unit, H corresponds to occupation of an H unit, and HL to ownership of both an H and an L unit (agents residing in H and renting out the other property).

Figure 8: Steady State Allocation



Note: End of period housing unit allocations by household type (horizontal lines) and age. Thresholds i_j^{age} determined endogenously indicated below each line. Allocations indicated above the type-line for each age. $\emptyset$ corresponds to homeless agents, R to renters, L and H to owner occupiers of low and high type units, respectively, and HL to landlords owning both a low and a high type unit. Case covered in the proof of Proposition 1 in the text.

In general, the relative position of all thresholds in steady state and, hence, the lifetime housing transitions, depend on model parameters. But we can use price bounds 5.1 to 5.3, price ordering $R(1-\gamma)^{-1} < p_L < p_H$ and assumptions 3.5 to 4.5 to show that steady state allocations will be similar to those represented in Figure 8, and display the following relationships between thresholds:

$$\begin{aligned} & i_R^y < i_L^y < 1 < i_H^y && i_H^o < i_L^y \\ & i_R^o < i_L^o < i_H^o < i_{HL}^o && i_L^y < i_{HL}^o < i_H^y \qquad (6) \\ & i_h^o < i_h^y \quad \text{for } h = \{R, L, H\} && \end{aligned}$$

5.3. *Credit Constraints and the Composition of Housing Sales*

Using the affordability thresholds above, we can write demands for different types of units for young and old agents, as well as rental supply.

$$D_1^R = i_L^y - i_R^y \qquad D_2^R = i_L^o \qquad S^R = 1 - i_{HL}^o$$

$$D_1^L = 1 - i_L^y \qquad D_2^L = i_H^o - i_L^o$$

$$D_2^H = 1 - i_H^o$$

Rental demand by young agents, D_1^R, is given by agents that can afford to rent but cannot afford a down-payment for an L unit. Demand for owner-occupation of low-type units will be given by the mass of agents who can afford the corresponding down-payment. Demands for old agents can be obtained analogously. Finally, supply of rental units is equal to the mass of landlords, which will be given by $S_R = 1 - i_{HL}^o$.

Now that we have all the expressions for demand and supply, we can re-write the housing market equilibrium conditions for the two property markets and the rental market. We are left with:

$$1 - i_H^o = S_H \tag{7.1}$$

$$i_L^y - i_R^y + i_L^o = 1 - i_{HL}^o \tag{7.2}$$

In addition to these equilibrium conditions we can also write down the expressions for transaction volumes as a result of the thresholds in i. Transactions of low units are equal to the mass of L units bought by young agents plus the mass of L units bought by old agents. These will be given by:

$$tr_L = 1 - i_L^y + i_H^o - i_L^o \tag{8}$$

$$tr_H = 1 - i_H^o \tag{9}$$

We can use the equilibrium conditions 7.1 and 7.2 to study how SS prices and allocations depend on γ and how a change in credit conditions affects the composition of housing transactions. This is the main result of this theoretical framework and is provided in Proposition 1.

Proposition 1

Steady states with lower γ have i) lower values of $\frac{tr_L}{tr_L + tr_H}$ and ii) higher values of S^R if housing allocations can be described by (6).

Proof: See Appendix B.

The proof uses market clearing conditions to identify how endogenous property prices respond to changes in γ. Combined with the expressions for tr_L, tr_H and S_R, these show that SS with tighter credit have a lower fraction of L transactions and a larger fraction of renters. The proposition can be proved analogously for steady-state allocations *different* from those outlined in 6. Several of these alternative cases are covered in Appendix B.[24]

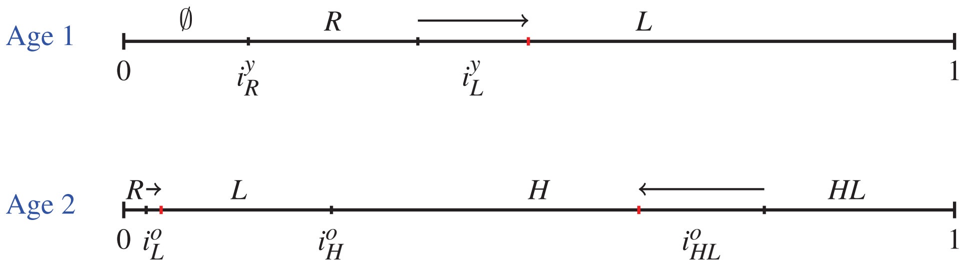
Tighter credit translates into lower SS prices in the L and H markets while leaving rents unaffected (given 5.3). As a result, the number of old households able to keep their low type home when moving up the ladder increases with smaller γ. Because old agents are better able to price out young prospective buyers when credit is scarce, an increase in γ increases the stock of renters living in low type dwellings. Transaction volumes of these units decrease with tighter credit as less households retain their starter properties when trading up. An illustration of the effect of credit tightening on the allocation of units is presented in Figure 9. The same proof can be used to show the opposite happens with *increased* credit availability.

5.4. *Transitions: Numerical Analysis*

The dynamic structure of the model links current wealth with prices in previous and subsequent periods. These, in turn, will be affected by credit conditions. As a result, it is unlikely that transitions between steady states will be instantaneous. In order to study these transitions, I now turn

[24]For example, proposition 1 can also be proved for the case in which some young agents own H units.

Figure 9: Change in Steady State for $\gamma' < \gamma$



Note: Figure displays the change in steady-state allocations resulting from a tightening of credit conditions. With tighter credit the fraction of agents retaining their L unit when moving up the ladder increases, as does the fraction of renters.

to a numerical analysis of the response of the key objects in proposition 1 (i.e. fraction of renters, transaction volumes) to an unexpected and permanent increase in down-payment requirements.

The code is set up to closely follow a discretized version of the recursive equilibrium definition that can be found in Appendix B. A discrete number N of agents are born each period, so that $2N$ agents demand housing at any point in time. Income distributions and parameters are chosen to satisfy assumptions 3.1 to 4.5, so that steady state allocations can be characterized by 6. The shock is modelled as an unexpected reduction in γ taking place in period 0. The transition path of prices p_L and p_H is selected so as to ensure markets clear throughout the transition period. Agents in the model are forward looking, so if future prices influence current decisions, the whole transition has to be solved for simultaneously. However, if v_L, v_H and μ values are sufficiently large, agents' decisions will continue to be solely determined by current credit conditions, as current utility flows strictly dominate the effect of future capital gains (or losses).[25]

The set of parameters used to illustrate transitions is provided in Table 5. Total housing stock is $S_L + S_H = 1950$ and $N = 1000$, so that only 2.5% agents will be priced out of the private housing market in equilibrium. Income distributions are uniform in all periods.[26] Incomes for old agents

[25] In order to determine transition prices, I first find the price vector that clears housing markets with myopic agents and then verify that this transition also clears the market when agents are forward looking. For sufficiently *low* values of v_L and v_H, or a sufficiently large change in γ the price paths for myopic and forward looking agents may not coincide. This is not the case for the parameters in Table 5.

[26] Uniform distributions are chosen for income because they allow to easily verify assumptions 3.5 to 4.5 are met. Examples of transitions for other distributions are provided in Appendix B.

are substantially larger than incomes for the young. Qualitatively, this is consistent with observed patterns and is required so that some old agents are able to price the young out of ownership at relatively high values of γ. The initial steady state is characterized by a maximum LTV of $\gamma = 0.85$. I separately study the transitions as a response of a drop to $\gamma_{f1} = 0.8$ and a drop to $\gamma_{f2} = 0.75$, both events representing a sudden tightening of credit.

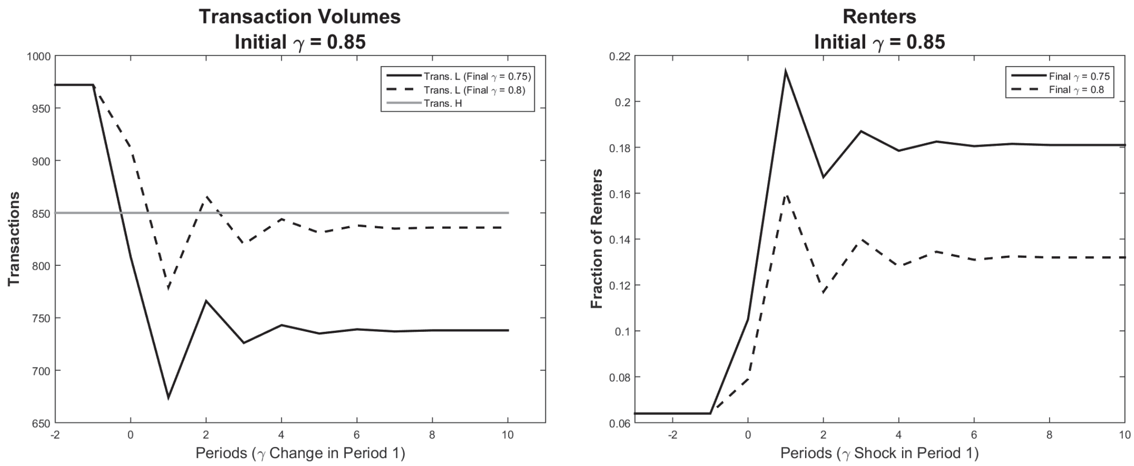
Table 5: Numerical Analysis: Parameter Values

Parameters	v_L	v_H	μ	S_L	S_H	r	γ_{i}	γ_{f1}	γ_{f2}
Value	200	280	0.5	1050	900	0.01	0.85	0.8	0.75
Income Distributions									
Period 1			$U[2,4]$						
Period 2			$U[3,20]$						
Period 3			$U[3,20]$						
# of Households (born in t)	1000								

Note: Parameters and income distributions for numerical analysis. Parameter γ_{i}, represents initial maximum LTV ratios, γ_{f1} indicates final γ after a 5 p.p reduction, and γ_{f2} indicates final γ after a 10 p.p reduction.

Transitions between steady states for LTV shocks of different magnitudes are reported in Figure 10. Shocks arrive in period 0. The left panel represents the evolution of transaction volumes for both L and H dwellings. Transactions of H dwellings are represented by the gray line. These are unaffected by credit tightening, as prices adjust to neutralize the shock and allocations do not change. The series for transaction volumes of L dwellings are represented in black lines. The solid and dashed lines represent the transition for a 10 p.p and a 5 p.p exogenous drop in LTV, respectively. In both cases we observe that sales of L units fall on impact, more so in the case of the larger shock, as expected. Transactions tr_L continue to fall one period after the shock, before oscillating to convergence subsequently. The right panel represents the change in the fraction of renters in response to the shock. Again, the fraction of renters increases on impact and on the period after the shock, and later oscillates to convergence. The initial effect of credit tightening is partially muted because old potential landlords start period 0 with a substantial amount of debt acquired under the high LTV regime. After these have passed, transactions reach their trough.

Figure 10: Transitions after Credit Shock



Note: **Left-panel** represents the time series of transaction volumes for H and L type dwellings. The horizontal axis represents time, and the vertical axis represents number of sales. The gray line corresponds to tr_H, and black lines correspond to tr_L. **Right-panel** represents the time series for the fraction of renters, represented in the vertical axis. An unexpected, permanent shock to credit conditions takes place in period 0. Solid lines represent transitions for a 10 p.p. drop in γ. Dashed lines represent transitions for a 5 p.p. drop in γ.

Oscillations also result from this initial difference.

Figure 10 reveals that, for this set of parameters, the intuition obtained from the comparative statics carries when looking at the transition period. When credit tightens, transactions fall at the lower end of the market and the fraction of renters increases as more old agents become landlords by holding to their starter house. It is important to note that other sets of parameters may lead to similar transitions. Appendix B provides a sensitivity analysis by discussing three examples for other parameter choices, including the case of non-uniform income distributions.

5.5. *Discussion*

Three comments are due regarding the model and its main results. The role of dual owners is critical to link transaction volumes with credit conditions, both in the short term and when comparing steady states. Note this differs from the mechanism in Ortalo-Magne and Rady (2006), in which trade-downs by older agents are used to link γ with transaction volumes. I do not include trade downs in this framework and certainly these do exist, but there is evidence that the scale of these housing market transitions is small (Yang (2009)).

The down-payment requirements are specified with the standard multiplicative form. However, it is necessary that collateralized borrowing is only available for one unit so that maximum borrowing in this context is $p_H\gamma$, even if a household owns multiple units. Otherwise, borrowing scales with the number of units, new prices exactly offset changes in credit conditions and allocations are unaffected by credit tightening.[27]

The model provides a channel linking credit conditions to the composition of transactions. The presence of a rental market is necessary for this channel to exist. The crucial role of rental markets has the advantage of being an implication from the mechanism that can be tested at the micro level. Intergenerational differences in the effects of credit tightening also play a crucial role in the model. Both aspects will be evaluated empirically in the next section.

6. Supporting Evidence

The model indicates that credit tightening increases renting by the young at the lower end of the market. The change in rented stock needed to house those renters comes from a reduction of sales in those segments. In this section, I present different estimates showing this mechanism can explain the results in sections 3 and 4. I show that the reduction in transaction volumes was stronger in LSOAs where renting increased. Therefore, the increase in rental supply was *not* provided by individual investors buying units to let. I also show that this correlation emerges exactly on 2008, as expected. Using individual data for a sample of English dwellings, I show that renting increased especially in relatively lower quality units after 2008. Finally, I also re-estimate equation 1 using the change in the fraction of renters as my outcome variable so as to directly test the effect of credit conditions on renting. Estimates show that changes in credit conditions had heterogeneous effects

[27] The fact that borrowing does not scale with housing wealth is broadly consistent with observed patterns in the Wealth and Assets Survey. That being said, this is a consequence of agent's decisions and not a constraint imposed by lenders. So we can interpret the non-scalability assumption as a reduced-form alternative to a full characterization of households' borrowing decisions.

on the fraction of renters across qualities.

I also show that there was an age pattern in the fall in transactions, with sales falling more in relatively young neighbourhoods. This is further evidence that it was houses typically bought by FTBs that experienced the strongest reduction in sales. Again, the correlation is observed after 2008, coinciding with the contraction in credit.

Evidence from the Rental Market

The fraction of people living as renters in England increased from 12.8% in 2008 to 16.4% in 2012.[28] But where did this extra supply of rented housing come from? Building activity had stalled. In addition, the number of buy-to-let loans had dropped abruptly after 2007 so it is unlikely that buy-to-let could provide the units for this increase in renting. Moreover, a rush of investor buying would have increased transactions at the lower rungs of the housing ladder, which is the opposite of what I report in my stylized facts. The model may provide an answer: when credit tightens the extra supply of rental units comes from increases in let-to-buy.

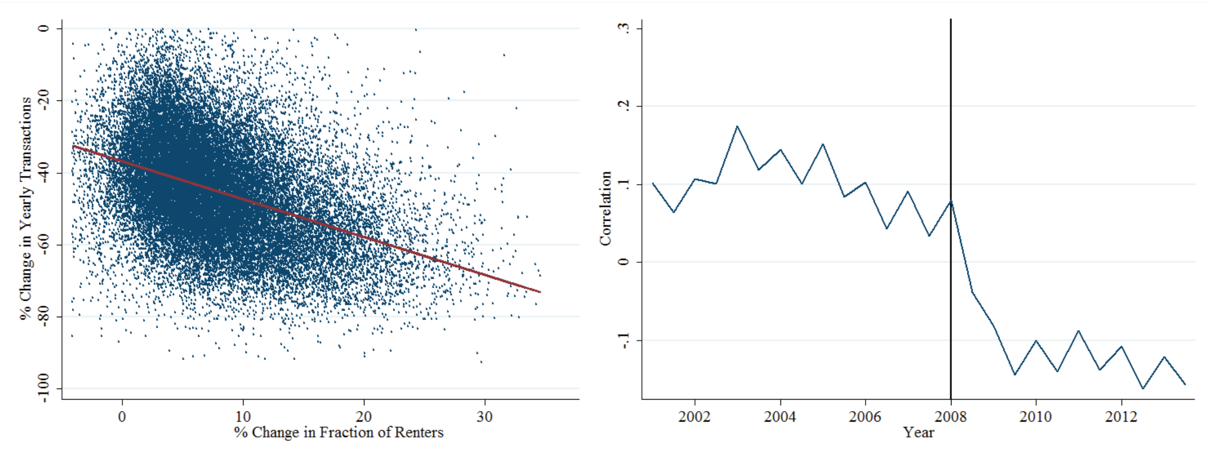
Disaggregated information on housing tenure is available at the LSOA level for the 2001 and 2011 census.[29] I use this information to compute the increase in the fraction of private renters over this period. I expect the change in renting will be negatively correlated with the change in average yearly transactions between the boom and bust periods. The corresponding scatter plot is presented in the left panel of Figure 11. I also use my 2007-2009 LSOA panel to estimate regressions of the change in renting on the change in transactions after including different sets of controls and/or TTWA fixed effects. Results are reported in Table A4 in Appendix A. In all specifications the correlation is negative and strongly significant.

While this correlation is suggestive, it is only consistent with the proposed explanation if it arises

[28] The evolution of the fraction of renters is reported in the left panel of Figure A10 in Appendix A. The right panel shows the evolution of aggregate buy-to-let lending.

[29] Unfortunately, disaggregated data on renting is not available at the yearly frequency. Most of the increase in renting over the 2001-2011 period took place after 2008. Moreover, the increase in renting between 2002 and 2008 was mainly fuelled by purchases by buy-to-let investors which should have a positive effect on transactions.

Figure 11: Rental Markets and Transaction Volumes



Note: **Left-panel**: Plots the drop in average yearly transactions between the boom (200-2007) and bust (2009-2011) periods at the LSOA level in the vertical axis against the increase in the fraction of renters over total households between 2001 and 2011 in the horizontal axis. The slope of the fitted linear equation is -1.05 and is significant at conventional levels. **Right-panel**: Time-series of the cross-sectional correlations between the difference in the fraction of renters between 2001 and 2011, and the number of transactions for each semester between 2000 and 2013.

after 2008, when credit tightening took place. To test this, I calculate the cross-sectional correlations between the $\Delta Rent_j$ and $trans_j$ for every semester between 2001 and 2011. The correlations are plotted in the right panel of Figure 11. A change in the sign of the correlation takes place during 2008, coinciding with credit tightening.

I can also use individual property data to show that the increase in renting after 2008 was concentrated on the lower end of the market, consistently with the model predictions. For this purpose, I use the English Housing Survey (EHS), a yearly survey of the English housing stock.[30] The EHS includes housing characteristics and prices which allow to estimate a hedonic model and obtain a proxy for housing quality using characteristics related to size (number of bedrooms, number of bathrooms, number of living rooms), building age and region of each unit. I then use this proxy to study how the quality composition of rented stock changed over time. A detailed account of this exercise is reported in Appendix A. The main result is that the quality composition of rented stock

[30] I use the waves between 2004 and 2011 and restrict my sample to owner-occupied and private rental dwellings.

was stable between 2004 and 2007, before changing abruptly in 2008 and stabilizing thereafter. The increase in renting was concentrated in relatively low-quality segments.

To directly test whether credit tightening caused these changes in rental markets, I re-estimate equation 1 using differences in the fraction of renters between 2001 and 2011 as my outcome variable. Estimates for variants of this specification are reported in Table 6. The main coefficient of interest is the effect of the interaction between ΔLTV and the standardized quality measure. We observe that it has the expected positive sign and is significant across all specifications. A tightening of credit conditions will lead to relatively higher renting in the lower end of the market. We also find a counter-intuitive positive effect of ΔLTV on renting in columns 1 to 3 and 5. This would indicate that credit tightening would lead to a *reduction* in renting on average. One potential explanation is that part of the change in renting may have happened before 2007 and could have been larger in markets with initially high LTV levels. To deal with this issue and other potential confounding factors, I also provide estimates including TTWA-fixed effects in columns 4 and 6. This yields positive coefficients on $\Delta LTV \times$ Quality, as expected, indicating that a reduction in LTVs will have a positive effect on renting for units below average quality. The coefficient is strongly significant for column 6, indicating that, for units with quality 1 s.d. below the mean, a 1 percentage point drop in LTVs increases renting by 0.353%. Note that the coefficient in column 4 is also positive, but not significant (p-value: 18%). With this caveat in mind, I interpret this as evidence that credit tightening leads to more renting at the lower end of the housing market.

Transactions and Household Age

Young households move to neighbourhoods where other young people live in search for lower prices, but also adequate local amenities, quality schooling, etc.[31] While the model in section 5 does

[31] The striking persistence of average age the LSOA level is evidence of this. LSOAs experienced a median change in the average age of their residents of only -0.1 between 2001 and 2011 with 90% of areas changing by less than 3 years. This persistence implies that the young move with the young (and the old with the old) on average.

Table 6: Change in Loan-to-Value and Fraction of Private Renting (OLS & IV)

	OLS		IV (ltv_{t-1})		IV (ltv_{1999})	
Δ LTV × Quality	0.153**	0.111**	0.165***	0.0995	0.475***	0.353***
	(0.08)	(0.05)	(0.06)	(0.07)	(0.09)	(0.08)
Δ LTV	0.118**	0.0965***	0.146***		0.676***	
	(0.05)	(0.04)	(0.05)		(0.22)	
Quality	0.590	0.770	1.106*	-0.116	3.167***	1.840***
	(0.94)	(0.62)	(0.57)	(0.69)	(0.63)	(0.59)
Controls	No	Yes	Yes	Yes	Yes	Yes
TTWA Effects	No	No	No	Yes	No	Yes
Observations	34309	34308	34308	34308	34291	34291

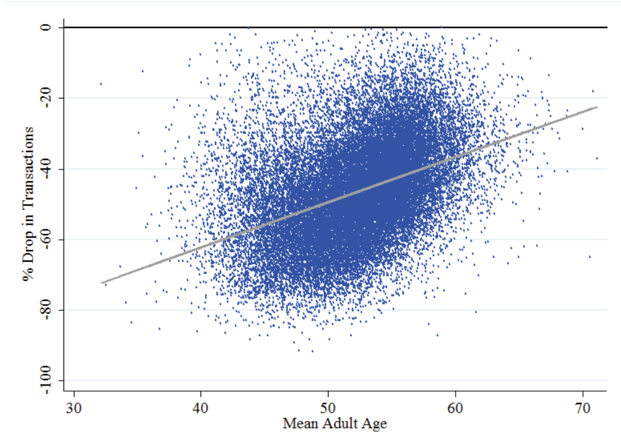
Notes: LSOA level regressions. Dependent variable in all specifications is the change in the fraction of households living in private renting accommodation taken between the 2001 and 2011 census. Columns 1 and 2 correspond to OLS estimates while the remaining columns correspond to IV estimates, with instruments indicated in the table header. Standard errors clustered at the TTWA level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

not explicitly distinguish between young and old neighbourhoods, it does predict less transactions by the young. I can test whether this is consistent with observed patterns.

For this purpose I use population and age structure data from the ONS disaggregated at the LSOA level for 2007. This allows me to know the fraction of population by age group for all the LSOAs in England and Wales. I combine this information with my transactions dataset to check if the drop in transactions and prices had an age profile. The results are illustrated in Figure 12. I plot the change in average yearly transactions between the pre-crisis (2000-2007) and crisis (2009-2011) periods against the mean adult (over 25) population for each LSOA. The upward sloping pattern is clear: transactions dropped less in areas populated by older households, with a correlation of 0.4.

Again, I test the robustness of this relationship by running a regression of the change in transactions between 2007 and 2009 on the mean adult age in a given LSOA. The resulting estimates are presented in Table A6 in Appendix A. Across specifications we observe that the coefficient on $\overline{Age}$ is positive and significant. These coefficients confirm the robustness of the correlation reported in Figure 12.

Figure 12: Difference in Transactions by LSOA Mean Age



Note: The figure plots the average change in yearly transactions between benchmark (1995-2007) and crisis periods (2008-2013) in the vertical axis and the mean adult age at the Lower Super Output Area level. Adults are defined as individuals of age above 25. The slope of the fitted linear equation is 1.27 and statistically significant at conventional levels.

7. Alternative Explanations

We know changing credit conditions are by no means the only possible driver of variation in housing turnover or tenure choice. The stylized facts documented in section 3 can also be the result of changes in the labour market, internal migration, and other forces affecting demand and supply in housing markets. I investigate several of these alternative explanations empirically and describe the main results of those analyses here. Outputs from of these exercises can be found in Appendix A.

First, I consider internal migration (within and between regions) as an alternative source of changes in composition. Housing transactions may be driven by geographical moves between or within a region, which may be horizonal (space) rather than vertical (quality). These moves were surely affected by the 2008 shock to labour markets which led to a generalized drop in internal migration.[32] Less moves between districts with lower prices could generate heterogeneous changes in volume across qualities. To test whether this was the case, I use origin-destination data on moves

[32]This type of transitions have sometimes been emphasized by the literature about the interaction between housing and labour markets (see Head and Lloyd-Ellis (2012), Rupert and Wasmer (2012), Nenov (2015) and the references therein).

at the district level from the ONS. I find no evidence that the reduction of between-district moves in 2008/2009 was concentrated in cheaper districts. In fact, these results suggest that internal moves fell more between relatively high-quality areas.

A change in composition could be induced by a change in prices, coupled with either nominal loss aversion or the increase in households underwater (i.e. with negative housing equity). I provide evidence that these are unlikely to explain away the stylized fact for housing volumes. Because the 2007 drop in housing prices was preceded by a long expansion, most of the households affected by these constraints had purchased between 2005 and 2007.[33] In Figure A6 of Appendix A, I show that excluding from the sample houses sold in this period does not remove the heterogeneous change in transaction volumes.

Finally, I analyse the potential impact of changes in unemployment and youth unemployment on the composition of sales. For this purpose, I exploit variation induced by a shift-share type instrument. While my instrumental variable estimates do confirm an effect of unemployment on transaction volumes, they do not support the hypothesis that unemployment shocks explain the composition of sales. Results and a description of this exercise are provided in the appendix. Increases in unemployment appear to disproportionately reduce transactions at the upper end of the market, so cannot explain a reduction in volumes at the other end.

These results are informative, but do not constitute a complete study of either of these mechanisms, which continue to be interesting objects for further analysis. Yet the tests referred to above do suggest that none of these drivers played an important role in explaining the stylized facts reported in this paper.

[33]The trough reached by price indices in 2009 had been previously crossed by the price series in 2005.

8. Conclusions

This paper presents evidence on the change in the composition of traded dwellings which occurred during the 2008/2009 downturn in the UK housing market. Using different methods to identify housing types, I arrive at the same conclusion: the fraction of transactions corresponding to cheaper housing units decreased markedly during the crisis, breaking a pattern of relative stability which had endured during the boom. I show that the large change in maximum Loan-to-Value ratios offered by British banks is a likely explanation for this change in composition. I link these two facts using a theoretical framework in which tighter credit constraints imply that younger, poorer households are priced out of the ownership market by richer households which retain their starter homes when trading up. The framework's predictions are consistent with recent observed changes in the rental market and changes in transactions by age of neighbourhood residents.

These results are novel in several aspects. In the first place, they show that the distribution of transactions may change over the housing cycle and provide a new stylized fact that could be used in other attempts to model how different market segments perform over time. Secondly, I provide a rationale for these changes in composition by incorporating changes in rental supply into the analysis. Finally, the empirical analysis confirms that deposit requirements can affect housing tenure. In this regard, my model suggests that initiatives seeking to reduce deposit requirements can be effective in increasing home-ownership rates. While the analysis here does not take into account the cost associated to these policies, it clarifies the mechanism through which credit conditions can simultaneously affect the ability of young households to get on the housing ladder and the supply of units for rent.

This paper opens several directions for further research. First, the change in the composition of transactions may be a general feature of housing cycles (such as the price-volume correlation) or something exclusive of the recent British experience. Understanding whether this is the case can help to provide a new fact around which to construct our housing models and motivate the standard composition adjustments that have characterized the construction of house price indices for decades. Secondly, other factors such as income shocks or changes in expectations could also affect the composition of sales. While some of these elements are discussed in section 7, they may warrant specific analyses of their own. Finally, ladder models such as the one presented here may be used to answer questions about housing affordability for the young, an ongoing problem in several cities that is increasingly attracting the attention of policy-makers and academics.

A. Additional Tables & Figures

This appendix includes several complementary tables and figures, all of which are mentioned in the article. I provide brief descriptions here to complement the discussion in the main text.

Table A1 provides the number of observations available in the full Land Registry Dataset over the 1995-2013 period and the number of observations removed after each subsequent sample restriction. The final row corresponds to the repeat-sales count which is built starting from the Final Sample and removing properties that are only recorded once (matches between subsequent sales based on addresses).

Table A1: Sample Restrictions

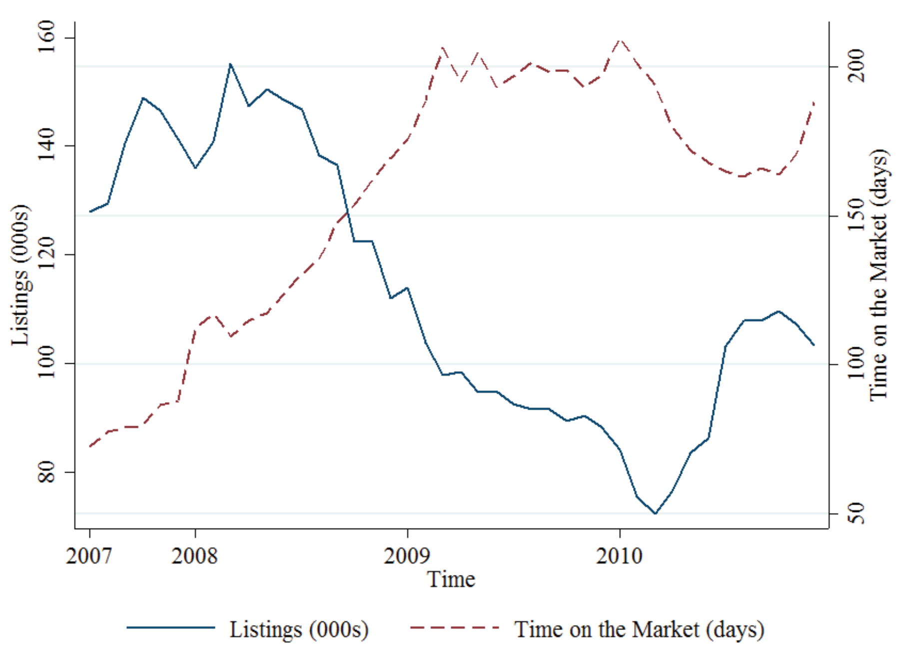
	Observations	% of Full Sample
Full Sample	18,744,353	100%
Leaseholds	4,301,626	22.9%
Newbuilds	1,904,779	10.2%
Missing Postcodes	18.640	0.1%
Final Sample	12,537,180	66.8%
Repeat-Sales Sample	9,342,390	49.8%

Note: Detailed account of sample restrictions for the Land Registry dataset.

Figure A1 represents the evolution of the number of listings and time on the market from the second half of 2007 up to 2010. Data corresponds to the six largest English cities (London, Birmingham, Manchester, Liverpool, Leeds and Sheffield). Data was obtained from `www.home.co.uk`, a property search website where real estate agents post listings. We observe a sharp decline in listings, coupled with an increase in time on the market during the same period. The change in listings lags the decline in transactions reported in Figure 2 by about six months.

Figure A2 shows segmentation by tenure in the housing market. I first obtain estimates of housing quality by estimating a hedonic model in which the log of reported housing values is regressed on a set of year effects, a set of region effects and a set of housing characteristics (number of bedrooms, number of bathrooms, number of living rooms, building age and a dummy taking value 1 for flats). Fitted values from this hedonic model are my quality measure. Figure A2 displays histograms

Figure A1: Listings & Time on the market

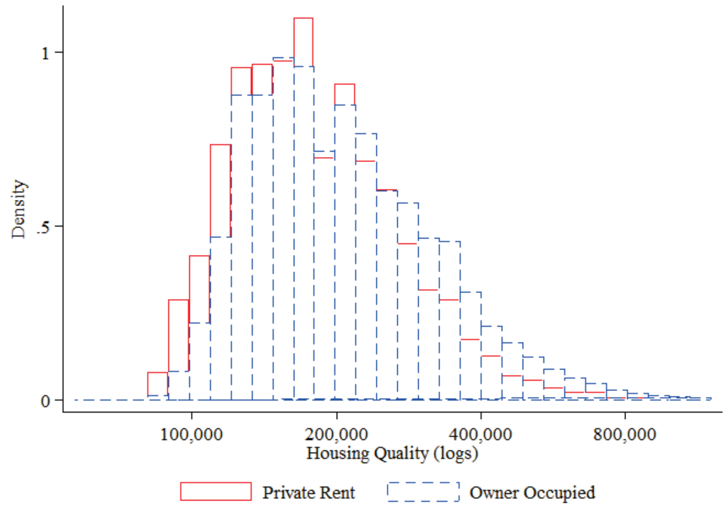


Horizontal axis represents time at the monthly frequency. The solid line represents the evolution of listings in the six largest English cities (left vertical axis). The dashed line represents average time on the market for these six cities, weighted by number of listings per city (right vertical axis).

for these quality measure for rented (solid line) and owner-occupied (dashed line) dwellings. We observe that the distribution of quality for rented dwellings is to the left of the distribution of quality for owner occupied dwellings. Unreported regression results show that this market segmentation *increased* as the crisis unfolded.

Figure A3 plots the frequency of yearly transactions for each postcode sector - dwelling type group relative to the benchmark (1995-2007) period in the vertical axis against the within city quality rank in the horizontal axis (as calculated in Section 3). Figures correspond to years 1997, 2000, 2003, 2006, 2009 and 2012, as shown. Figures are normalized so that the average over ranks is equal to one. A horizontal distribution indicates that the relative frequency of transactions across ranks was close to the average in the pre-crisis period. We can see this is the case in 1997, 2000, 2003 and 2006. However, after 2009 we observe a clearly upward sloping graph. This indicates that transactions at the upper end of the market became relatively more frequent after the housing bust.

Figure A2: Housing Quality and Tenure

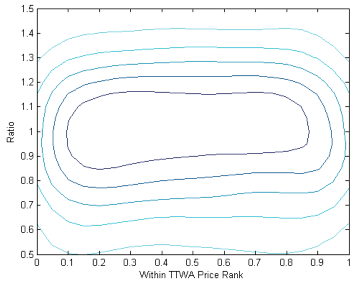


Histograms of housing quality for rented dwellings (solid line) and owner occupied dwellings (dashed line). Quality obtained as fitted values from a hedonic model (see text). Data obtained from the English Housing Survey for the period 2004-2011.

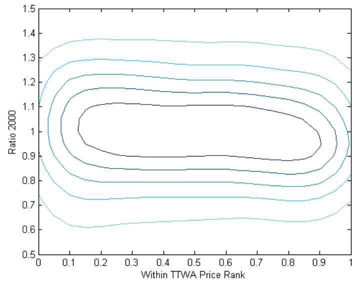
Figure A4 shows evidence that the assumption of fixed quality of a unit over time is reasonable in this context. Quality is defined above as a fixed attribute of a house. However, it is clear that the price a house may seek in the market at different times may differ substantially. In order to evaluate whether my assumption is plausible, I compute quality estimates for the same units at different time periods. I estimate quality for Postcode Sector-Dwelling type pairs for three time periods: 1998-2002, 2003-2007 and 2008-2012, using location-type groups. Next I construct diagrams comparing quality estimates in these periods. Results are presented in Figure A4. They show the rank correlation plots for estimated qualities computed over 2003-2007 and 1998-2002 (top-left), 2008-2012 and 2003-2007 (top-right), and 2008-2012 and 1998-2002 (bottom). In all cases the estimated correlation is larger than 0.9. This indicates that qualities estimated using this method are stable and that the assumption of fixed quality is reasonable for the period under consideration.

In Figure A5, I document the stylized fact for the change in volumes and prices by considering a much simpler definition of quality: dwelling type. Detached and Terraced units combined amounted to over 65% of all transacted dwellings since 2000. These types had, respectively, the highest and lowest average prices in England and Wales. I consider these two groups of properties and

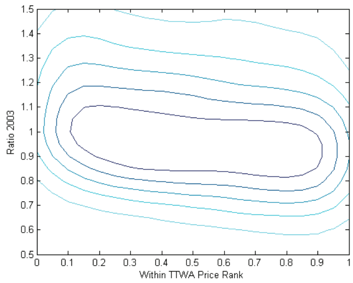
Figure A3: Yearly Composition Relative to 1995-2007 Period



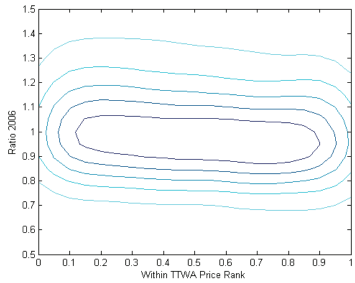
(a) 1997



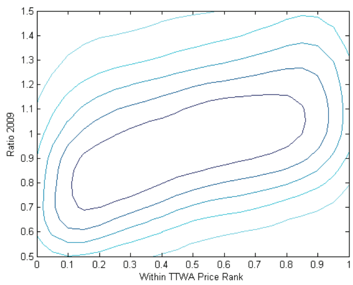
(b) 2000



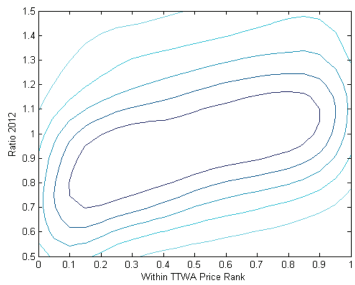
(c) 2003



(d) 2006



(e) 2009

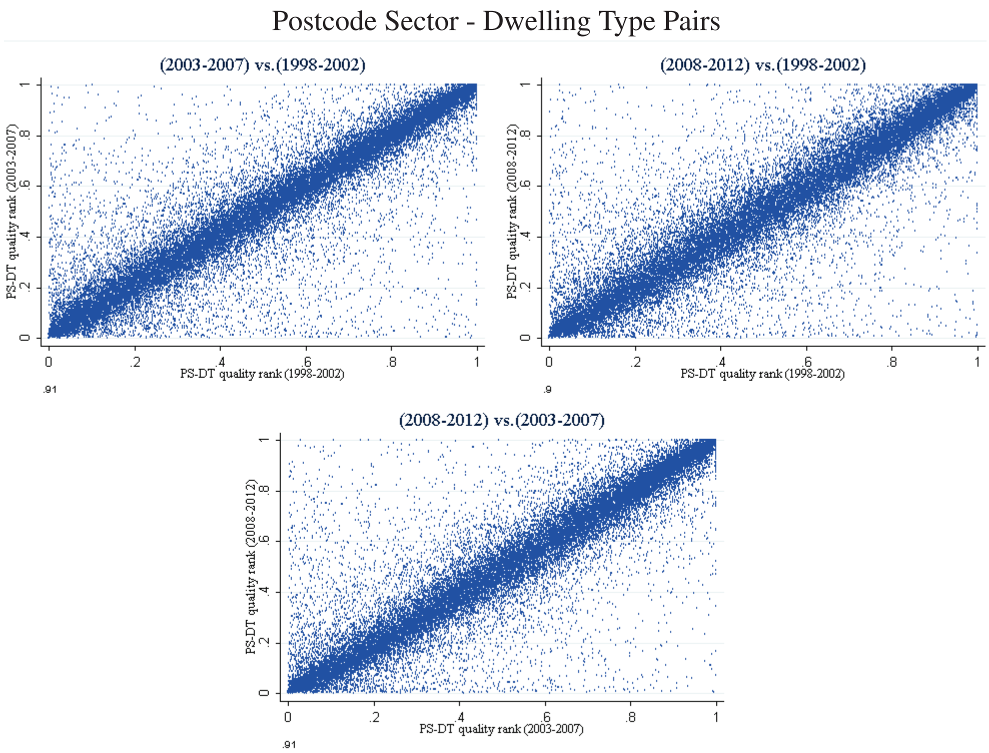


(f) 2012

Variable in the Vertical axis represents the fraction of transactions in the specified year relative to the average yearly number of transactions in 1995-2007. Horizontal axis represents the within-TTWA quality rank calculated using postcode sector-dwelling type groups as shown in Section 3. The figure plots the contour plot of an Normal kernel density estimate with bandwidth chosen according to Silverman's rule-of-thumb. A horizontal plot corresponds to a year in which the average transactions across qualities was similar to the one in the benchmark 1995-2007 period. An upward sloping plot corresponds to years in which transactions at the high end of the market were relatively more frequent.

track the evolution of their share of total sale volumes as well as their prices, after a seasonal adjustment. Results are presented in Figure A5. In the left panel we can see terraced house prices fell by 15.1% between late 2007 and mid 2009. The price drop for detached housing was slightly lower (13.6%). Regarding transactions (right panel), the fraction of sales corresponding to each

Figure A4: Quality Rank Correlations



Rank correlation plots of the quality estimates for periods (1998-2002), (2003-2007) and (2008-2012). Qualities estimated estimated at the level of PS-DT pairs. Top-Left: Rank correlation plot for quality estimated in (2003-2007) and (1998-2002). Top-Right: Rank correlation plot for quality estimated in (2008-2012) and (2003-2007). Bottom: Rank correlation plot for quality estimated in (2008-2012) and (1998-2002).

Figure A5: Detached and Terraced Housing

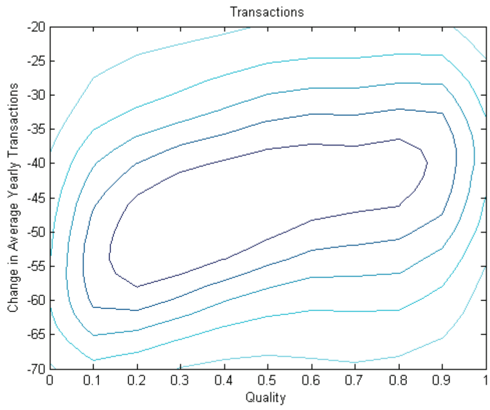
Left: Evolution of prices for detached and Terraced houses. Normalized to 100 at Q1 2008. Price indices constructed using repeat-sales methodology. **Right**: Fraction of total transactions corresponding to detached and terraced houses.

type changed abruptly during 2008. Detached houses increased their share of total sales by four percentage points, roughly the decrease in the fraction corresponding to terraced dwellings.

The dataset used to show the stylized facts in section 3, did not use data from new builds or leasehold transactions. Figure A6 is analogous to the plot presented in the bottom panel of Figure 4 in the main text but includes data for these two types of transactions. As we can see, the qualitative picture is the same: average yearly transactions after 2008 fell more for relatively lower quality housing.

Figures A7 and A8 illustrate the representativeness of the Nationwide data in terms of both transaction volumes and, importantly, the evolution of Loan-to-Value ratios. Firstly, Figure A7 shows the correlation between the transaction volume figures in both the Land Registry and the Nationwide datasets for different geographies. The left panel shows the correlations when transactions are aggregated up to English and Welsh districts. The correlation is visibly very high, exceeding 0.9. At a more disaggregated level, the correlation is somewhat lower but still comfortably above 0.5. Hence, in terms of coverage, the lender's data is reasonable representative of total volumes, particularly when looking at moderately aggregated figures. Note that the Nationwide data is used to compute average LTV ratios at the city (TTWA) level. Secondly, Figure A8 (extracted from Kuvshinov (2010)) is analogous to Figure 7 in the main text, but extracted from data on total lending

Figure A6: Including Newbuilds and Leaseholds



Postcode Sector - Dwelling Type Pairs

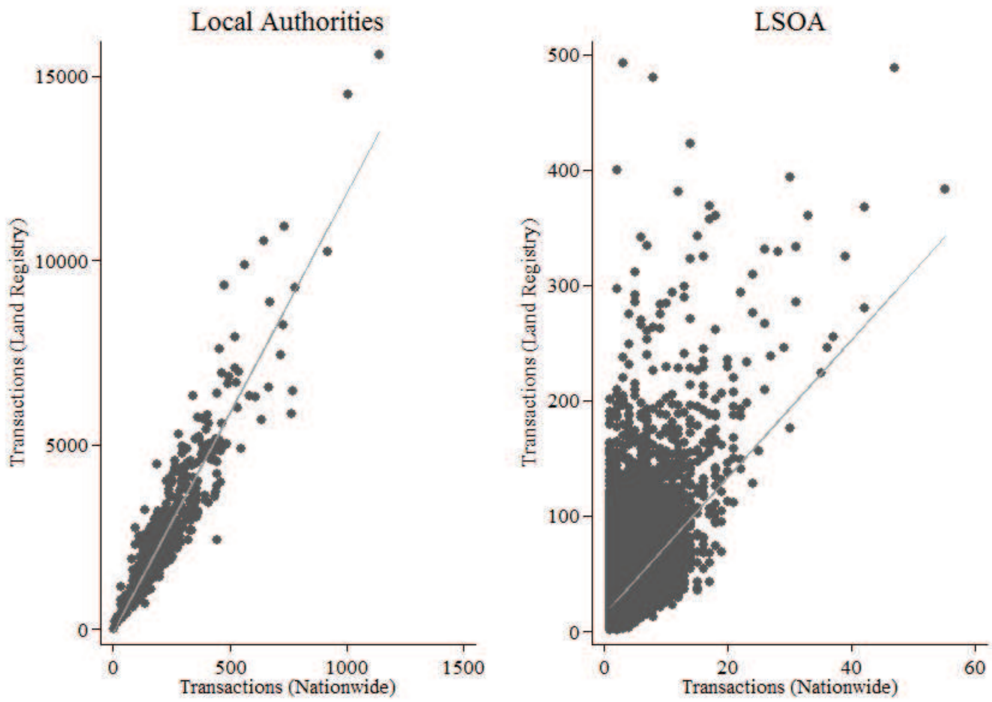
Plot of the change in yearly transactions between 2007 and 2009 against the within-TTWA quality rank. Leaseholds and newbuilds included in the calculation of transaction volumes. The cross-sectional unit is the postcode sector-dwelling type pair. The figure plots the contour plot of an Normal kernel density estimate taken over the resulting scatter plot, with bandwidth chosen according to Silverman's rule-of-thumb.

from the Council of Mortgage Lenders. The resemblance between the two figures is striking.[34]. This illustrates the fact that the Nationwide data is successful in capturing the general changes in LTV distributions over this period.

Figure A9 is provided as evidence that the reduction in LTVs that took place in 2008 was largely supply-driven. The figure represents a weighted measure of banks responses regarding the evolution of different relevant variables including availability of credit in panel I, maximum LTV ratios in panel II, scoring criteria for borrowers in panel III, the fraction of approved mortgage applications in panel IV, the availability of credit by LTV ratio in panel V, and changes in maximum required loan-to-income ratios in figure IV. From these we can conclude that there was a substantial tightening of credit conditions between late 2008 and early 2009. Note that this circumstance was not undone in the subsequent periods as changes oscillated around 0 between late 2009 and 2011. In addition, we see in panels II and V that this tightening was mainly channelled through a reduction in

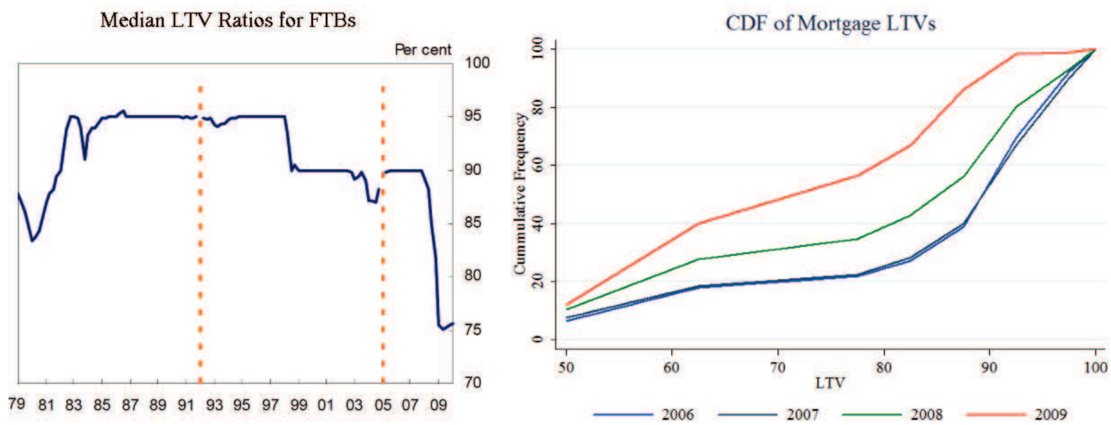
[34]The fact that the left panel in Figure A8 does not have mass points in certain values is a consequence of its being constructed with relatively aggregated data from the CML source

Figure A7: Transaction Volumes in Land Registry and Nationwide Datasets



Left-panel: Represents transaction volumes in 2007 and 2009 by district in the Land Registry (vertical axis) and the Nationwide datasets (horizontal axis). Line corresponds to fitted values from a univariate regression. Raw correlation is 0.93 (0.92 in 2007 and 0.94 in 2009). **Right-panel:** Represents transaction volumes in 2007 and 2009 by Lower Super Output Areas in the Land Registry (vertical axis) and the Nationwide datasets (horizontal axis). Line corresponds to fitted values from a univariate regression. Represented data restricted to LSOAs with less than 500 transactions in a year (8 LSOA-year pairs excluded as outliers). Raw correlation for full sample is 0.58.

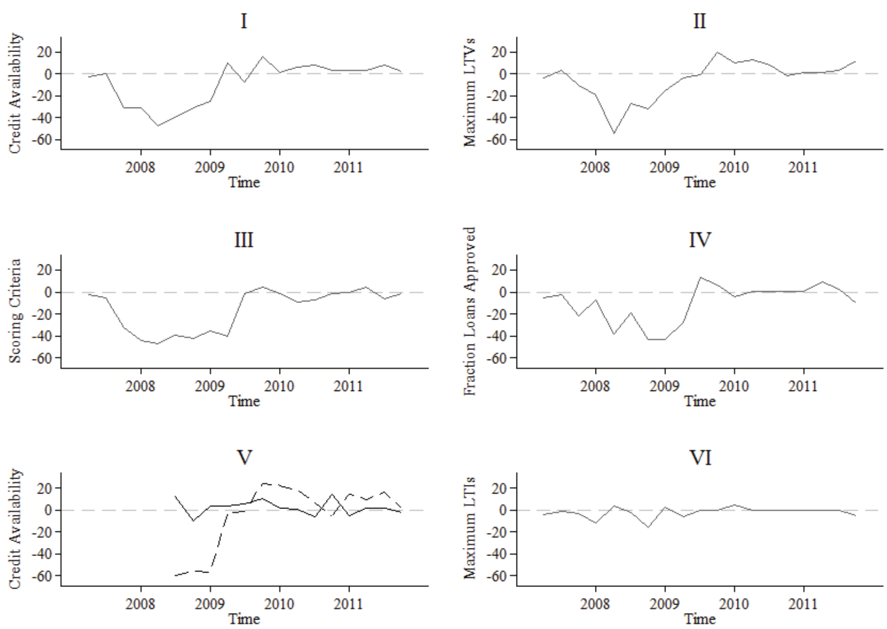
Figure A8: LTVs Median and Distribution (CML)



Left: Vertical axis plots the median Loan-to-Value ratio on mortgages granted to first-time buyers in percentage and the horizontal axis plots years. Graph extracted from Kuvshinov (2010). Original data from Council of Mortgage Lenders (CML). **Right:** Cumulative distributions of LTVs for First Time Buyers for years 2005, 2007, 2008 and 2009. (Source: CML).

maximum LTV ratios and the availability of high LTV lending. Interestingly, panel VI shows there was no substantial change in maximum loan-to-income ratios. Observed changes in bank fees and the evolution of LIBOR rates over this period (not reported) indicate that other lending constraints did not change during this period. In sum, these results show that i) there was a substantial, supply-driven tightening of credit conditions between 2008 and 2009; and ii) that this tightening was largely expressed via a reduction in the availability of high LTV mortgages.

Figure A9: Changes in Lending Conditions - Credit Conditions Survey



Panels I through VI constructed using the Bank Of England's Credit Condition Survey. Each corresponds to one survey question. Vertical axis represents positive/negative responses for each question, normalized to take values between 100 and -100. Horizontal axis represents time (quarterly frequency). The question in panel I asks for *changes* in the availability of credit in the three months prior to the time of the survey for each quarter (positive values indicating increase in credit). The question in panel II asks for changes in maximum LTV ratios. The question in panel III asks for changes in the stringency of credit scoring criteria (negative indicating tighter lending criteria). The question in panel IV asks for changes in the fraction of approved loan applications. The question in panel V asks for changes in secured credit availability by LTV with solid lines indicating low LTVs (under 75%) and dashed lines indicating high LTVs (over 75%), with data starting in Q3 2008. Finally, the question in panel IV asks for changes in maximum loan-to-income ratios.

Table A2 presents descriptive statistics for the city level variables used in Section 4. Credit conditions are measured using mean Loan-to-Value ratios to First-time buyers in 2007 and 2009. Changing labour market conditions are measured using the change in unemployment, employment and inactivity rates as well as mean and median wages as recorded in the Labour Force Survey

Table A2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
LTV (2007)	76.074	7.266	33.333	88.635	186
LTV (2009)	68.595	7.15	17.694	85	186
D. Unemp	1.512	1.817	-5.225	7.107	186
D. Employ	-0.793	3.546	-12.9	9.875	186
D. Inactive	-0.358	3.203	-9.1	12.65	186
D. SelfEmp	-0.1	2.691	-8.125	10.125	186
D. Seekers	0.979	0.342	0.273	1.953	186
D. Prof. Emp	0.041	3.085	-14.45	13.2	185
D. High Edu Emp	0.709	4.916	-23.3	15.7	186
D. Mean Wage	31.61	43.809	-253.1	305.5	186
D. Median Wage	25.999	27.312	-178.6	90.100	186

Note: Descriptive statistics for the city level variables. Variables LTV (2007) and LTV (2009) are average LTVs to First-time Buyers taken across TTWAs. The other variables are, respectively, the change in unemployment, employment and activity rates, the change in the fraction of self-employed workers, in the fraction of benefit seekers, in the fraction of employment in professional and high education sectors, in the mean wage, and in the median wage.

(LFS), and the Annual Survey of Hours and Earnings. I also include the change in the fraction of population receiving job-seeker's allowance, the change in the fraction of population who is self-employed, in the fraction of workers in professional sectors, and in the fraction of workers with higher education, also obtained from the LFS. We can see that the average LTV to first time buyers was substantially lower in 2009 than in 2007. Between 2007 and 2009 unemployment rates increased on average 1.5 percentage points (mean taken across cities) and, conversely, the employment rate fell around 0.8%. TTWA populations in 2007 ranged between roughly 9000 inhabitants in Hawes & Leyburn and over 8.5 million in London. When handling the data before estimation, I identified two outliers in mean LTVs, observations which are more than two standard deviations below the first percentile of the LTV distribution each year. These are the minima indicated in the first two rows of Table A2 and correspond to the TTWAS of Brecon in 2007 and Pwllheli in 2009, both with populations under 30,000. Results are qualitatively robust to keeping these observations in place but in all reported estimates I have replaced these values of LTVs with the first percentile of the respective yearly distributions (50.9% and 41.3%, respectively).

Table A3 provides estimates for a modified specification of equation 1 which includes interaction terms between our Quality measure and each of the controls. Estimation is carried out via two-step least squares with the instruments being ltv_{2007} in the first column 1 and ltv_{1999} in the second column. P-values of joint significance tests for the coefficients of the interaction terms provided in the table foot. See Section 4 in the main text for interpretation of these results.

Table A3: Interactions

	IV	
Δ LTV × Quality	-0.0155***	-0.0508***
	(0.00)	(0.02)
Δ LTV	0.0122**	-0.0103
	(0.00)	(0.03)
Δ Unemp. × Quality	-0.00195	-0.0153
	(0.01)	(0.03)
Δ Emp. × Quality	-0.00184	-0.0120
	(0.01)	(0.03)
Δ Inactive × Quality	-0.000172	-0.0123
	(0.01)	(0.03)
Δ Self.Empl. × Quality	-0.00146	0.00383
	(0.01)	(0.01)
Δ Job Seekers × Quality	1.925**	1.010
	(0.97)	(1.06)
Δ Prof.Empl. × Quality	-0.000739	-0.00234
	(0.01)	(0.01)
Δ Mean Wage × Quality	-0.0000532	0.000387
	(0.00)	(0.00)
Δ Youth Unemp × Quality	0.00143	0.00131
	(0.00)	(0.00)
Joint Sig. P-value	.42	.67
R^2	0.13	0.09
Observations	33572	33555

Notes: Dependent variable is the change in transactions in all specifications. IV estimation of equation 1 in the main text, including interaction terms of all controls with the Quality variable. Joint significance test p-values for these interactions' coefficients reported in the table footer. Columns 1 and 2 estimated with each of my instruments.

Figure A10 presents relevant descriptive information on the evolution of rental markets between the the early 2000s and 2012. The left-panel represents the fraction of English households living as renters obtained from the EHS. The right-panel represents the numbers of buy-to-let mortgages provided by British banks according to the CML.

Figure A10: Rental Market

Left: Percentage of units occupied through private rental. Vertical line corresponds to 2008. Source: English Housing Survey. **Right**: Number of buy-to-let loans (in thousands) distributed to UK households over the 2003-2012 period. Source: CML.

Tables A4 and A6 display partial correlations between the change in transactions taken over the 2007-2009 period and the change in renting (2001-2011) and average adult age, respectively. These estimates highlight the robustness of the correlations documented in Figures 11 and 12.

Table A4: Change in Renting and the Fall in Transactions

	Δ log(trans)			
Δ Fract. Renters	-1.600***	-1.202***	-0.936***	-0.680***
	(0.102)	(0.308)	(0.290)	(0.160)
Quality		0.174***	0.129***	0.174***
		(0.030)	(0.022)	(0.008)
Controls	No	No	Yes	Yes
TTWA Effects	No	No	No	Yes
R^2	0.02	0.13	0.15	0.20
Observations	33573	33573	33572	33572

Notes: LSOA (census area) level regressions. In all columns the dependent variable is the log difference in housing transactions taken between 2007 and 2009. Changes in the fraction of renters, included as regressor in all columns, taken between census (2001-2011). List of control variables as detailed in section 4. Standard errors clustered at the TTWA (city level.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

I can use individual dwelling data on unit characteristics and housing tenure to verify that the quality composition of rental stock changed during and after 2008. I first obtain quality estimates as fitted values of a regression of property values on housing characteristics.[35] I use this quality measure to estimate:

[35] For this purpose I use self-assessed property values, as reported in the EHS from 2008 under variable *valout*.

$$rented_i = \beta_1 \widehat{Quality} + \beta_2 \widehat{Quality} \times Crisis_t + \delta_t + \eta_r + \epsilon_i$$

where $rented_i$ is a dummy taking value 1 for rented units, $\widehat{Quality}$ are fitted values from the hedonic regression, and δ_t and η_t are time and region effects, respectively. Estimates for parameters β_1 and β_2 are provided in column 3 of Table A5. We observe that both β_1 and β_2 are negative. This implies that low quality properties are more likely to be rented throughout the whole period, but that this bias increases after 2008. In column 4, I include a full set of interactions between $\widehat{Quality}$ and year dummies. We can see that, throughout the period, quality has a negative correlation with the probability of renting, but this slope is stable between 2004 and 2007 and increases in 2008. This shows that after 2007 renting increased more at the lower end of the market, which is consistent with the model assumptions and the mechanisms emphasized there.

Table A5: Change in the Composition of the Rented Stock

	(1) Rented House	(2) Rented House	(3) Rented House	(4) Rented House
House Quality	-0.0708***	-0.177***	-0.165***	
	(0.00)	(0.01)	(0.01)	
House Quality × Post 2008			-0.0145*	
			(0.01)	
House Quality × $Year^{2004}$				-0.133***
				(0.01)
House Quality × $Year^{2005}$				-0.126***
				(0.01)
House Quality × $Year^{2006}$				-0.136***
				(0.01)
House Quality × $Year^{2007}$				-0.130***
				(0.01)
House Quality × $Year^{2008}$				-0.165***
				(0.01)
House Quality × $Year^{2009}$				-0.171***
				(0.01)
House Quality × $Year^{2010}$				-0.180***
				(0.01)
House Quality × $Year^{2011}$				-0.186***
				(0.01)
Region FE	N	Y	Y	Y
Year FE	N	Y	Y	Y
R^2	0.00797	0.0377	0.0378	0.0378
Observations	139020	139020	139020	139020

Note: Dwelling-level regressions using data from the English Housing Survey (repeated cross-sections), between 2004 and 2011. Dependent variable is a dummy taking value 1 for rented units. Quality measured in log price points and obtained as fitted values from a hedonic regression of housing valuations on size measures, built year and a set of region effects. Survey weights used in all specifications. Regional and time effects included in columns 2, 3 and 4. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A6: Mean Age and the Fall in Transactions

	Δ log(trans)			
$\overline{Age}$	0.0255***	0.0220***	0.0187***	0.0122***
	(0.00)	(0.00)	(0.00)	(0.00)
Quality		0.173***	0.134***	0.166***
		(0.02)	(0.01)	(0.01)
Controls	No	No	Yes	Yes
TTWA Effects	No	No	No	Yes
R^2	0.05	0.15	0.16	0.21
Observations	32789	32789	32788	32788

Notes: LSOA (census area) level regressions. In all columns the dependent variable is the log difference in housing transactions taken between 2007 and 2009. Average adult age (over 25) in 2007, included as regressor in all columns. List of control variables as detailed in section 4. Standard errors clustered at the TTWA (city) level.

* p < 0.1, ** p < 0.05, *** p < 0.01.

B. Appendix - Theoretical Framework

In this Appendix I provide derivations and proofs for the Model presented in section 5. These are organized as follows:

1. Recursive Equilibrium Definition.
2. Indirect Utilities in Steady State.
3. Steady State Price Bounds.
4. Parameter Restrictions and SS Allocations.
5. Proofs of Proposition 1.
6. Sensitivity Analysis of Transitions.

B.1. ***Recursive Equilibrium Definition***

The recursive competitive equilibrium consists of a set of states of the economy X (see state variables below), a set of decision rules for housing purchases, tenure choice and renting out decisions (see choice variables and constraints), value functions (see decision rules), property price functions ($P_L(x)$, $p_H(x)$, $R(x)$) mapping the state of the economy to the real line, and a law of motion for the state of the economy. Conditions for these objects to configure a recursive competitive equilibrium are provided below.

B.1.1. State Variables

The state of the economy at the beginning of every period is given by:

$$x = (h(i, 2), h(i, 3), b(i, 2), b(i, 3))$$

where functions $h(i, 2)$ and $h(i, 3)$ map agent types i to their property holdings (of L and H units) at the beginning of ages 2 and 3, respectively. Function $b(i, 2)$ and $b(i, 3)$ record non-housing assets for agent of type i at the beginning of ages 2 and 3, respectively.

$h(i,a) = (h_L(i,a), h_H(i,a))'$

with

$h_L(i,2), h_L(i,3) : [0,1] \to \mathbb{N}^+$

$b(i,2), b(i,3) : [0,1] \to \mathbb{R}$

B.1.2. Choice Variables

In every period agents decisions determine housing assets for the beginning of the next period $h'(i,x,a)$, next period assets $b'(i,x,a)$, tenure choice $\tau'(i,x,a)$ and the decision to rent out property $\lambda'(i,x,a)$, all of which are defined for $a = \{1,2\}$.

B.1.3. Constraints

There are three constraints on agents' decisions. Budget constraints, credit constraints and constraints associated to housing tenure decisions. The first constraint determines the law of motion of non-housing assets. Credit constraints determine the set of feasible housing asset combinations. Housing tenure decisions determine feasible values of $\tau'(i,x,a)$.

Budget constraint (law of motion of non-housing assets) for $a = \{1,2\}$[36]

$$b'(i,b,h,h',x,a) = (1{+}r)\left(e_a(i)(1 - 1\{\tau'(i,a) = 0\}) + b(i,a) - c - P^{own}(h'(i,x,a) - h(i,a)) + R(\lambda'(i,x,a) - \tau_R'(i,x,a))\right)$$

Credit Constraints (Mortgage on only one unit) for $a = \{1,2\}$

$$\Gamma(i,b,h,h',x,a) = \{h' \in \mathbb{N}^2 : e_a(i){+}b{+}P^{own}h(i,x,a) \geq \gamma(max\{P_L(x)1\{h_L' > 0\}, p_H(x)1\{h_H' > 0\}\})\}$$

Tenure Constraints (can only owner occupy if you own) for $a = \{1,2\}$

$$\tau_L'(i,x,a) \in \{1,0\} \quad \text{if } h_L'(i,x,a) \geq 1$$

$$\tau_L'(i,x,a) = 0 \quad \text{if } h_L'(i,x,a) = 0$$

$$\tau_H'(i,x,a) \in \{1,0\} \quad \text{if } h_H'(i,x,a) \geq 1$$

$$\tau_H'(i,x,a) = 0 \quad \text{if } h_H'(i,x,a) = 0$$

[36]Recall $P^{own} = (P_L, p_H)$.

B.1.4. Value Functions and Decision Rules

Policy functions labelled as f_h for housing assets and f_τ for housing tenure and f_λ for decisions to rent out property. Decision on non-housing assets follows from law of motion of wealth. I define these and the value functions here.

Housing Assets

$$f_h(i,x,1) \text{ solves } v_1(i,x) = \max_{h' \in \Gamma(i,0,0,h',1)} v_2(i, b'(i,0,0,h',1), h', x')$$

$$f_h(i,x,2) \text{ solves } v_2(i,x) = \max_{h' \in \Gamma(i,b,h,h',x,2)} u_h(\tau(i,2)) + \beta v_3(i, b'(i,b,h,h',2), h', x')$$

$$f_h(i,x,3) \text{ solves } v_3(i,x) = \max_{h' \in \Gamma(i,b,h,h',x,3)} u_h(\tau(i,3)) + b + P^{own}(h-h') - b'(i,b,h,h',x)$$

Note that $v_3(i,x)$ includes h' and b' entering with a negative sign. Arguments for functions $h(i,a)$ and $b(i,a)$ omitted for brevity.

Landlord

$$\lambda(i,x,a) = \begin{cases} h'_L(i,x,a) - \tau'_L(i,x,a) + h'_H(i,x,a) - \tau'_H(i,x,a) & \text{if } R(x) \geq 0 \\ 0 & \text{Otherwise} \end{cases}$$

Housing Tenure

For sufficiently large v_L, v_H and $v_H - v_L$

$$\tau(i,h,a) = \begin{cases} (0,0,1) & \textit{if } h_H(i,x,a) \geq 1 \\ (0,1,0) & \textit{if } h_L(i,x,a) \geq 1 \ \& \ h_H(i,x,a) = 0 \\ (1,0,0) & \textit{if } b + e_a(i) > R(x) \ \& \ h_H(i,x,a) = 0 \ \& \ h_L(i,x,a) = 0 \end{cases}$$

B.1.5. Housing Market Clearing

$$\int h'(i,x,2) + h'(i,x,3)d\,i = (S_L, S_H)'$$

$$\int \lambda'(i,x,2) + \lambda'(i,x,3)d\,i = \int \tau_R'(i,x,2) + \tau_R'(i,x,3)d\,i$$

B.1.6. Law of Motion

Because both the housing tenure and the decision to become a landlord are determined solely by housing market decisions, the law of motion of this economy is given by:

$$b(i,2) = b'(i,0,0,f_h(i,x,1),1)$$

$$b(i,3) = b'(i,b(i,2),h(i,2),f_h(i,x,2),1)$$

$$h(i,2) = f_h(i,x,1)$$

$$h(i,3) = f_h(i,x,2)$$

B.2. ***Indirect Utilities in Steady State***

Given my assumption on the discount rate (namely, that $\beta(1+r) \geq 1$) we can assume without loss of generality that agents will delay all consumption to age 3. In steady state, all prices faced by agents are the same in periods 1, 2 and 3 of their lifetimes. It is straightforward to solve for utility as a function of $e_2(i)$, $e(i)$ and $e_3(i)$ for each lifetime path of tenure choices (e.g.: rent as young and buy high as old, buy low as young and invest in a low house when old, etc.).

Indirect utilities for each path of lifetime tenure choices are the following:[37]

$$V^{\emptyset,\emptyset} = \beta^2[e_3(i)]$$

$$V^{\emptyset,R} = \beta^2[e_2(i)(1+r) + e_3(i) - (1+r)R] + \beta^2\mu v_L$$

$$V^{R,R} = \beta^2[e(i)(1+r) + e_3(i) - R((1+r) + (1+r)^2)] + \beta^2\mu v_L + \beta\mu v_L$$

$$V^{R,L} = \beta^2[e(i)(1+r) + e_3(i) - R(1+r)^2 - rp_L] + \beta v_L + \beta^2\mu v_L$$

$$V^{L,L} = \beta^2[e(i)(1+r) + e_3(i) - (r^2 + 2r)p_L] + \beta v_L + \beta^2 v_L$$

$$V^{R,H} = \beta^2[e(i)(1+r) + e_3(i) - R(1+r)^2 - rp_H] + \beta\mu v_L + \beta^2 v_H$$

$$V^{L,H} = \beta^2[e(i)(1+r) + e_3(i) - (r^2 + r)p_L - rp_H] + \beta v_L + \beta^2 v_H$$

$$V^{L,HL} = \beta^2[e(i)(1+r) + e_3(i) - (r^2 + r)p_L + (1+r)R - rp_H] + \beta v_L + \beta^2 v_H$$

Steady state prices p_L and p_H are necessarily smaller than $e(1)/(1-\gamma)$ (the maximum wealth an old agent in this economy can have, scaled by the down-payment requirement). Other price bounds are provided in the main text. Therefore, by assumption 3.1 on preference parameters, owner occupation is always worth its user cost. Rents R are pinned down by the income distribution, so that $R = e_1(2 - S_L - S_H)$ if rental markets exist (see expression 5.3 in the main text). Using assumptions 3.1 to 3.4 on preference parameters, in combination with these price bounds and operating with the expressions for indirect utilities we can conclude that:

$$V_{L,HL} > V_{H,L} > V_{L,L} > V_{R,H} > V_{R,L} > V_{R,R} > V_{\emptyset,R} > V_{\emptyset,\emptyset}$$

*B.3. **Steady State Price Bounds***

B.3.1. Proof (P_H Upper bound)

I prove here that $p_H \leq e(1 - S_H)(1-\gamma)^{-1}$, expression 5.1 in the text.

[37] Super-indices indicate lifetime transitions. E.g. $V^{\emptyset,R}$ corresponds to indirect utility for agents living in social housing (or with parents) at the beginning of period 2 and renting at the beginning of period 3. Naturally, other transitions are possible, yet under the assumptions invoked here, they will never arise in equilibrium.

Assuming $p_H > e(1-S_H)(1-\gamma)^{-1} \rightarrow$ Down-payment necessary to buy an H type unit is $(1-\gamma)p_H > e(1-S_H)$. Therefore, only a mass of agents smaller than S_H would be able to afford this down-payment, (note that assumption 4.2 ensures old agents with $i = 1-S_H$ have more wealth than all young agents in SS). As a result, markets would not clear, so $p_H \leq e(1-S_H)(1-\gamma)^{-1}$.

B.3.2. Proof (P_L Lower bound)

I prove here that in SS, $p_L \geq e_1(2-S_L-S_H)\,(1-\gamma)^{-1}$, expression 5.2 in the text.

Proceed by contradiction. So suppose $P_L < e_1(2-S_L-S_H)\,(1-\gamma)^{-1} \rightarrow$ required down-payment $p_L(1-\gamma) < e_1(2-S_L-S_H) \rightarrow$ mass of age 1 agents who *can* buy a type L unit is $m_L^1 > 1-(2-S_L-S_H) = S_L+S_H-1$.

Under the counter-factual assumption and given 4.1, all age 2 agents would be to buy a type L unit $\rightarrow m_L^2 = 1$. Hence we have that the total mass of agents able to buy L type units would be $m_L^1 + m_L^2 > S_L + S_H$ (note the strict inequality).

Up to a mass S_H of these agents buy an H unit instead. This leaves us with the contradictory statement that a mass of agents larger than S_L would reside in L units for these SS prices. This cannot be the case in equilibrium so $P_L \geq e_1(2-S_L-S_H)\,(1-\gamma)^{-1}$.

B.3.3. Proof ($R = e_1(2-S_L-S_H)$)

I prove here that, if rental markets exist, $R = e_1(2-S_L-S_H)$, expression 5.3 in the text. We again proceed by contradiction.

Assume $R < e_1(2-S_L-S_H)$. Under this condition and given assumption 3.2, households who are unable to owner-occupy would be willing to to rent. Total mass of agents who could then afford a rent would be larger than $2-S_L-S_H$ in age 1, and 1 in age 2. This would again break market clearing conditions (excess demand), so in equilibrium $R \geq e_1(2-S_L-S_H)$.

If $R > e_1(2-S_L-S_H)$ and rental markets do exist, then a mass of more than $2-S_L-S_H$ young agents would remain homeless at the end of each period. This implies housing markets do not clear (excess supply of housing units) and $R \leq e_1(2 - S_L - S_H)$.

So, if rental markets exist, $R = e_1(2 - S_L - S_H)$.

Note that in the absence of rental markets we can follow a similar analysis to show that in equilibrium we would need $P_L = e_1(2 - S_L - S_H)(1 - \gamma)^{-1}$.

B.3.4. Existence of rental Markets

I prove here that under assumptions 3.1 to 4.5, rental markets exist in steady state. A participation and an incentive constraint need to be satisfied for this purpose: Some households have to be able to own two units, and there have to be incentives to become a landlord.

Assumption 4.3, combined with the price bound for p_H, ensures that at least a mass $1 - S_H$ of old agents can simultaneously own an L and an H property and rent it out.

There will be incentives to be a landlord if and only if $R > r P_L$.[38] This is ensured by combining an upper bound on L prices $(e_1(1)(1 - \gamma)^{-1})$ with bound 5.3. Hence, 3.5 ensures that there are incentives to become a landlord.

B.4. ***Parameter Restrictions and SS Allocations***

Here I provide the proof regarding the class of steady state allocations feasible under assumptions 3.1 to 4.5. These are included in the text as conditions on the relative sizes of i thresholds given in 6 (see main text).

[38] Note that only low type units would be available for rent in equilibrium. This is a consequence of the fact that all rental units yield the same utility μv_L, combined with the equilibrium condition $p_H > p_L$.

$$i_R^y < i_L^y < 1 < i_H^y \tag{10}$$

$$i_R^o < i_L^o < i_H^o < i_{HL}^o \tag{11}$$

$$i_h^o < i_h^y \quad \text{for } h = \{R, L, H\} \tag{12}$$

$$i_H^o < i_L^y \tag{13}$$

$$i_L^y < i_{HL}^o < 1 \tag{14}$$

I first show the expressions for the relevant thresholds for the young (i_L^y, i_H^y, etc.) and then proceed to prove the inequalities above one by one. Finally, I provide the final expressions for the thresholds for old agents.

Expressions for Rental and Ownership Thresholds - Young Agents

Expressions for all the relevant thresholds for young agents will be given by:

$$i_R^y = e_1^{-1}(R) \tag{15.1}$$

$$i_L^y = e_1^{-1}(p_L(1-\gamma)) \tag{15.2}$$

$$i_H^y = e_1^{-1}(p_H(1-\gamma)) \tag{15.3}$$

$$i_{HL}^y = e_1^{-1}(p_H(1-\gamma) + p_L) \tag{15.4}$$

The case of thresholds for old agents is slightly more involved because it depends on previous decisions when young.

Proof: $i_R^y < i_L^y < 1 < i_H^y$

Condition 10 follows from the relation on prices $R < (1-\gamma)p_L < (1-\gamma)p_H$. Note in addition that given assumption 4.1 and bound 5.3, we will also have that $i_R^o < 0$, meaning that all old agents can afford to rent.

It remains to show that $1 < i_H^y$. This follows from assumption 4.2, indicating that $e_1(1) < e(1-S_H) - e_1(2-S_L-S_H)$. Richest young agents (those with $i = 1$), have less resources that a mass S_H of old agents. Note that young agents will be priced out of high quality ownership by some old agents even if the latter rented when young.

***Proof** ($i_h^o < i_h^y$ **for** $h = \{L, H\}$)*

Condition 12 can be proved using $e_1(i) < e_2(i)\,\forall i$. I will show that $i_L^o < i_L^y$ (proof of the same condition for H units is very similar).

Note that $i_L^y = e_1(p_L(1-\gamma))$. Proceeding by contradiction, if $i_L^o > i_L^y$, then marginal old buyers of L units bought L when young and therefore:

$$e(i_L^o) = e_1(i_L^o)(1+r) + e_2(i_L^o) = (1-\gamma)p_L + rp_L$$

$$e_1(i_L^o) > (1-\gamma)p_L$$

$$e_2(i_L^o) > (1-\gamma)p_L > rp_L$$

The first equality and the second and third inequalities cannot be true simultaneously (recall $r < 1-\gamma$). Therefore $i_L^o > i_L^y$ cannot be true. Hence, $i_L^o \leq i_L^y$. Proceed analogously to rule out the case of equality. Therefore, $i_L^o < i_L^y$.

Proof: $i_H^o < i_L^y$

This condition means marginal H owner occupiers when old were renters in period 1. This is ensured by assumption 4.2, which implies that a mass of S_H old agents can become landlords, pricing out young agents with $i = 1 - S_H$. This means that old agents with $i = S_H$ have enough wealth to buy both an H property, and an L property with $p_L = e_1(1-S_H)/(1-\gamma)$. Therefore,

$$e(S_H) > p_H(1-\gamma) + e_1(1-S_H)/(1-\gamma)$$

which is true given upper bound 5.2 for p_H and assumption 4.2.

Proof: $i^o_R < i^o_L < i^o_H$

Condition 11 is true given price ordering $R < p_L < p_H$ and what we know about period one choices from condition 13.

Consider statement $i^o_L < i^o_H$. We know from 13 that $i^o_H < i^y_L$. Given that no young agents own H units, we also know $i^o_H = 1 - S_H$. Given that $S_L > 1$, no old agents were homeless or social renters when young. Hence, $i^o_H = e^{-1}(p_H(1-\gamma) + R(1+r))$. Two cases are possible for i^o_L:

$$i^o_L = \begin{cases} e^{-1}(p_L(1-\gamma) + R(1+r)) & \text{if rented when young} \\ e_2^{-1}(p_L(1-\gamma)) & \text{if social housing/living with parents when young} \end{cases}$$

Because $e^{-1}(.)$ is strictly increasing, we know $i^o_L < i^o_H$ if households with $i = i^o_L$ rented when young. If these agents were in social housing or living with parents when young, then $i^o_L < i^o_H$ because old agents were renters (and young renters have higher incomes).

Statement $i^o_R < i^o_L$ can be proved analogously.

Proof **($i^y_L < i^o_{HL} < 1$)**

The final condition 14 relates to the lifetime transitions of landlords. The fact that marginal landlords where not renters nor owner occupiers of an H unit when young $i^o_{HL} \in (i^y_L, i^o_H)$ is important for proposition 1 because this ensures some key households experience a transition at age 2 in which they keep their starter unit when trading up the ladder. The statement $i^o_{HL} > i^y_L$ can be proved using assumption 4.4.

We proceed by contradiction. If $i^o_{HL} < i^y_L$, then landlords in period 2 were renters in period 1:

$$i^o_{HL} < i^y_L$$

$$e(i^o_{HL}) = p_H(1-\gamma) + p_L + (1+r)R$$

and therefore

$$e_1(i^o_{HL}) < p_L(1-\gamma)$$

$$e_2(i^o_{HL}) > p_H(1-\gamma) + (\gamma(1+r)-1)p_L + (1+r)R$$

Using the last equation combined with the bounds on prices 5.1, 5.2 and 5.3, this leads to $e_2(i^o_{HL}) > e(1-S_H) + (2+r)e_1(2-S_L-S_H)$. Note that this cannot be the case given assumption 4.4. The statement that $i^o_{HL} < 1$ follows from the proof of existence of rental markets provided in this appendix.

Dual** L **Owners

A final point is due regarding the possibility of dual ownership of low type units. A household could, in principle, own two L units in steady state, whether if they owner-occupy one and rent another out, or because they owner-occupy an H dwelling and rent out two L units. These cases ruled out by assumptions 4.4 and 4.5.

I first show that assumption 4.5 rules out the presence of landlords who are owner-occupiers of L units. To see this, it suffices to show that $p_L(2-\gamma) - R > p_H(1-\gamma)$. Price bounds 5.1 and 5.2, imply:

$$p_L \geq e_1(2 - S_L - S_H)/(1-\gamma)$$

$$p_H < e(1 - S_H)/(1-\gamma)$$

Therefore:

$$\frac{(2-\gamma)}{1-\gamma} e_1(2 - S_L - S_H) > e(1 - S_H) \rightarrow p_L(2-\gamma) - R > p_H(1-\gamma) \tag{16}$$

The statement to the left of 16, is satisfied by assumption 4.5 (replace price bounds as appropriate), and is a sufficient (not necessary) condition ruling out households owning two L and no H dwellings.

Finally, I show that assumption 4.4 ensures no households own three dwellings in steady state (i.e. two L and one H). This condition can be written as:

$$e(1) < p_H(1-\gamma) + p_L(2+r) - 2 * R$$

Given price bound for H and 4.3

$$e(1) < e(1 - S_H) + \frac{2+r}{1-\gamma} e_1(1 - S_H) - 2e_1(2 - S_L - S_H)$$

which is true given assumption 4.4

Expressions for Rental and Ownership Thresholds - Old Agents

While conditions in (6) restrict the set of potential lifetime transitions, we still have to proceed on a case by case basis to obtain expressions for the housing allocation thresholds for old agents. I discuss here the case illustrated in Figure 8 in the main text. Other cases yield analogous conclusions regarding the effects of credit tightening. With these lifetime transitions, the thresholds for old agents will be given by:

$$i_R^o = e^{-1}(R) \tag{17.1}$$

$$i_L^o = e^{-1}(p_L(1-\gamma) + R(1+r)) \tag{17.2}$$

$$i_H^o = e^{-1}(p_H(1-\gamma) + R(1+r)) \tag{17.3}$$

$$i_{HL}^o = e^{-1}(p_H(1-\gamma) + rp_L) \tag{17.4}$$

The first threshold is determined by rental affordability, the second by the ability of old agents to afford a down-payment. Note that the second threshold also depends on rental prices because marginal buyers of L dwellings of age 2 were renters in period 1 (see Figure 8).

B.5. *Proofs of Proposition 1*

Proposition 1 states that steady states with lower γ have i) lower values of $\frac{tr_L}{tr_L + tr_H}$ and ii) higher values of S^R if housing allocations can be described by 6.

Proof

Define functions $g(.) \equiv \frac{\partial e^{-1}(x)}{\partial x}$ and $g_a(.) \equiv \frac{\partial e_a^{-1}(x)}{\partial x}$. Total differentiation with respect to γ in 7.1 and 7.2 yields:

$$-\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right) g(p_H(1-\gamma) + R(1+r)) = 0 \tag{18}$$

$$\begin{aligned}\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma) - p_L\right) (g_1(p_L(1-\gamma)) + g_2(p_L(1-\gamma))) = \\ - g(p_H(1-\gamma) + p_L(1+r) - R) \left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H + (1+r)\frac{\partial p_L}{\partial \gamma}\right)\end{aligned} \tag{19}$$

From equation 18 we can conclude that the sum in the first parenthesis is equal to 0. In addition, substituting in the second term of equation 19 and proceeding by contradiction,[39] we conclude that:

$$\frac{\partial p_H}{\partial \gamma}(1-\gamma) = p_H \qquad (20) \qquad\qquad \frac{\partial p_L}{\partial \gamma}(1-\gamma) \in (0, p_L) \qquad (21)$$

Conditions 20 and 21 tell us how prices change with γ, and how the type thresholds i are affected by a tightening of credit conditions. The final step of the proof is to identify the implications of these conditions for transaction volumes (by unit type) tr_L and tr_H, as well as determining how γ affects the rental market. Operating from 8 and 9 we obtain:

$$\frac{d\,tr_H}{d\gamma} = -g(p_H - R(1+r))\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right) = 0$$
$$\frac{d\,tr_L}{d\gamma} = -(g_1(p_L(1-\gamma)) + g_2(p_L(1-\gamma)))\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma) - p_L\right)$$

Combining these expressions with 20 and 21 we conclude that $\frac{d\,tr_L}{d\gamma} > 0$ and $\frac{d\,tr_H}{d\gamma} = 0$, which suffices to prove the first statement of the proposition for the SS allocation in Figure 8. The second statement relates to the fraction of renters. Note that for this allocation we will have that $S^R = 1 - e^{-1}(p_H(1-\gamma) + (1+r)p_L - R)$. Total differentiation w.r.t. γ combined with the results for the price derivatives leads to:

$$\frac{dS_R}{d\gamma} = -\left((1+r)\frac{\partial p_L}{\partial \gamma} + \frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right) g(p_H(1-\gamma) + (1+r)p_L) < 0$$

■

B.5.1. ***Other Cases***

The text provides a proof of Proposition 1 for a specific steady state allocation satisfying:

$$i^y_H > 1 > i^o_{HL} > i^y_L > i^o_H > i^o_L > i^o_R > i^y_R \qquad (22)$$

[39] The resulting expression can be re-written as $\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma) - p_L\right)K_1 = -\left((1+r)\frac{\partial p_L}{\partial \gamma}\right)K_2$ where K_1 and K_2 are strictly positive. Condition 21 follows from this equation.

Assumptions 3.1 to 4.5 provide constraints on the feasible steady state allocations. Within those constraints, a steady state configuration different from 22 is possible, featuring no old renters. Moreover, the proof can also be extended to cases beyond those permitted under the selected parametric assumptions. I discuss three examples of this below. The first is that of an allocation that differs from the allocation in Figure 8 in that there are no old renters. In the second case, marginal H buyers when old were home-owners when young. In the third case, some young households are owner-occupiers of H dwellings when young.

Allocation I $\left(i^o_{HL} > i^y_L > i^o_H > i^o_L > i^y_R > 0 > i^o_R\right)$

This case is similar to the one discussed in the text but now there are no old agents living as renters. Note that given these allocations the relevant thresholds will be given by:

$$i^y_R = e_1^{-1}(R)$$

$$i^y_L = e_1^{-1}(p_L(1-\gamma))$$

$$i^o_H = e^{-1}(p_H(1-\gamma) + (1+r)R)$$

$$i^o_{HL} = e^{-1}(p_H(1-\gamma) + (1+r)p_L - R)$$

In this context we will have that the expressions for market clearing conditions and transaction volumes for L units and H units are:

$$S_L = 1 - i^y_L + i^o_H + 1 - i^o_{HL}$$

$$S_H = 1 - i^o_H$$

$$tr_L = 1 - i^y_L + i^o_H$$

$$tr_H = 1 - i^o_H$$

Total differentiating the market clearing conditions relative to γ we obtain:

$$0 = -A_1\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma) - p_L\right) + A_2\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right) + A_3(1+r)\left(\frac{\partial p_L}{\partial \gamma}\right)$$
$$0 = B_1\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right)$$

where $A_1 = g_1(p_L(1-\gamma)$, $A_2 = g(p_H(1-\gamma) + R(1+r)) - A_3$, $A_3 = g(p_H(1-\gamma) + (1+r)p_L - R)$ and $B_1 = g(p_H(1-\gamma) + (1+r)R)$ are strictly positive and functions $g(.)$ and $g_1(.)$ are as defined in the proof of the baseline case. From these expressions we can proceed by contradiction to obtain:

$$\frac{\partial p_L}{\partial \gamma}(1-\gamma) \in (0, p_L) \qquad\qquad \left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right) = 0$$

These conditions can be used to prove both statements of the proposition for this case by total differentiation of tr_L, tr_H and $S^R = 1 - i^o_{HL}$, as in the text.

Allocation II $\left(i^o_{HL} > i^o_H > i^y_L > i^o_L > i^y_R\right)$

This is the case in which young agents cannot own a high type unit and marginal old owner occupiers of an H dwelling owner occupied an L unit when young (in opposition to the case treated in the text, where marginal H buyers rented when young). In this context we will have that the expressions for the relevant thresholds are:

$$i^y_L = e_1^{-1}(p_L(1-\gamma))$$
$$i^o_L = e^{-1}(p_L(1-\gamma) + (1+r)R)$$
$$i^o_H = e^{-1}(p_H(1-\gamma) + rp_L)$$
$$i^o_{HL} = e^{-1}(p_H(1-\gamma) + (1+r)p_L - R)$$

The market clearing conditions and SS transaction volumes for L units and H units are:

$$S_L = 1 - i_L^y + i_H^o - i_L^o + 1 - i_{HL}^o$$

$$S_H = 1 - i_H^o$$

$$tr_L = 1 - i_L^o$$

$$tr_H = 1 - i_H^o$$

Total differentiation of the market clearing conditions w.r.t γ leads to:

$$0 = -A_1\left(\frac{\partial p_L}{\partial}(1-\gamma) - p_L\right) + A_2\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H + r\frac{\partial p_L}{\partial \gamma}\right) - A_3\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H + (1+r)\frac{\partial p_L}{\partial \gamma}\right)$$
$$0 = -B_1\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H + r\frac{\partial p_L}{\partial \gamma}\right)$$

where A_1,A_2,A_3 and B_1 are strictly positive. Working with these expressions and proceeding by contradiction we can conclude that:

$$0 = -A_1\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma) - p_L\right) - A_3\left(\frac{\partial p_L}{\partial \gamma}\right)$$

This implies that $\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma)\right) \in (0, p_L)$. Now, total differentiation of the expressions for transactions tr_L and tr_H yields:

$$\frac{\partial tr_H}{\partial \gamma} = 0$$
$$\frac{\partial tr_L}{\partial \gamma} > 0$$

which proves the first statement of the proposition. Finally, total differentiation of rental supply S_R w.r.t. γ yields:

$$\frac{d S_R}{d\gamma} = -g(p_H(1-\gamma) + p_L(1+r) - R)\frac{\partial p_L}{\partial \gamma} < 0$$

Allocation III $\left(i^y_H > i^o_{HL} > i^y_L > i^o_H > i^y_R > i^o_L > 0\right)$

This case is similar to the case discussed in the text but now a fraction of high income young agents owner occupy an H unit in period 1. In this context we will have that the expressions for the relevant thresholds are:

$$i^y_R = e_1^{-1}(R) \qquad i^o_L = e_2^{-1}(p_L(1-\gamma))$$

$$i^y_L = e_1^{-1}(p_L(1-\gamma)) \qquad i^o_H = e^{-1}(p_H(1-\gamma) + (1+r)R)$$

$$i^y_H = e_1^{-1}(p_H(1-\gamma)) \qquad i^o_{HL} = e^{-1}(p_H(1-\gamma) + (1+r)p_L - R)$$

Market clearing conditions and steady state transactions for L units and H units are:

$$S_L = (i^y_H - i^y_L) + i^o_H - i^o_L + (1 - i^o_{HL})$$

$$S_H = 2 - (i^y_H + i^o_H)$$

$$tr_L = i^y_H - i^y_L + (1 - i^y_H) + (i^o_H - i^o_L)$$

$$tr_H = 1 - i^y_H + i^y_H - i^o_H = 1 - i^o_H$$

Taking total derivatives w.r.t γ in the market clearing conditions and substituting we are left with expressions:

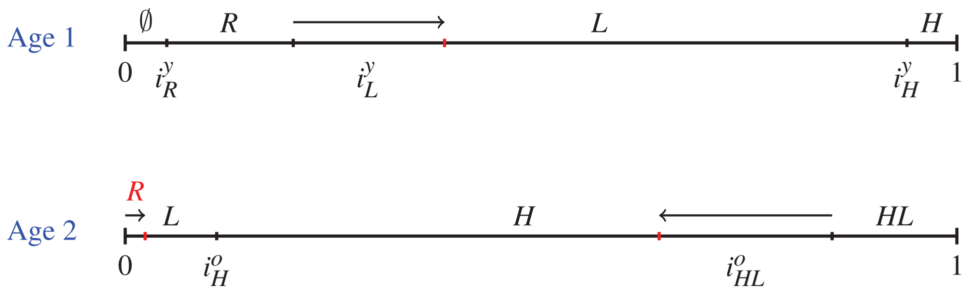
$$0 = A_1\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right) - A_2\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma) - p_L\right) + A_3\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H + (1+r)\frac{\partial p_L}{\partial \gamma}\right)$$

$$0 = B_1\left(\frac{\partial p_H}{\partial \gamma}(1-\gamma) - p_H\right)$$

Proceeding by contradiction, we can show that these two conditions can only be met by $\frac{\partial p_H}{\partial \gamma}(1-\gamma) = p_H$ and $\left(\frac{\partial p_L}{\partial \gamma}(1-\gamma)\right) \in (0, p_L)$. These two results can be used to prove both statements of the proposition as in the cases above (total differentiate expressions for transactions and rental supply, proceed by contradiction).

The change in steady state allocations in response to a reduction in maximum LTVs (a decrease in γ) is illustrated in Figure B11 for this case. The economic mechanism is identical to the one displayed in the main text. The steady state allocation of H units is unaffected by γ because changes in SS prices offset differences in credit availability.

Figure B11: Change in Steady State for $\gamma' < \gamma$
Young H Owner Occupiers



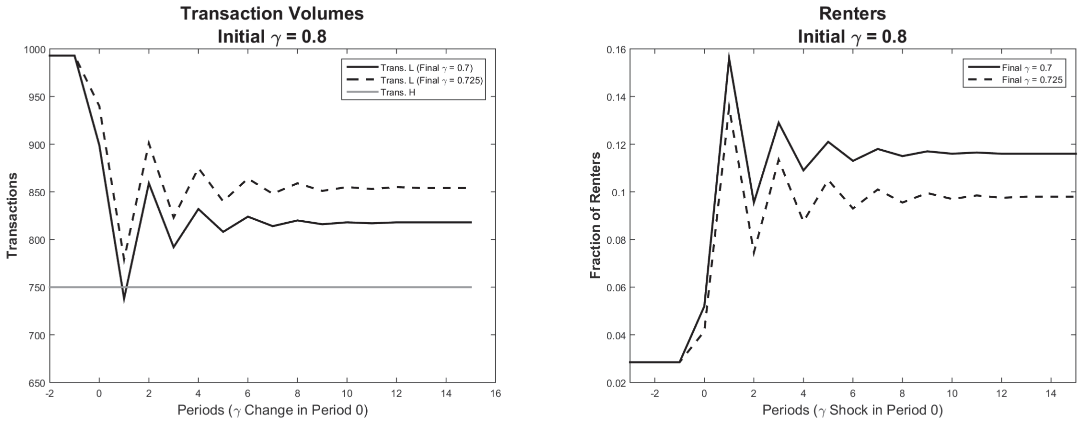
Note: Figure displays the change in steady-state allocations resulting from a tightening of credit conditions when a fraction of young agents are owner occupiers of H units.

B.6. Sensitivity Analysis of Transitions

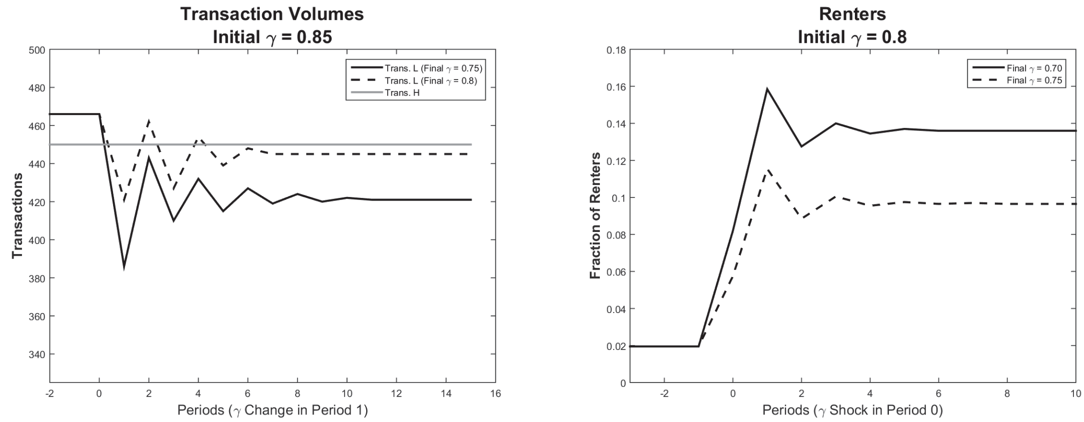
This section presents parameter sensitivity tests for the transitions between steady states. Three cases different from the one provided in the main text are considered here. The choice of parameters for these cases are provided in Table B7. In config I, the set of parameters is consistent with assumptions 3.1 to 4.5. Cases II and III do **not** satisfy these assumptions. As indicated in the text, the parametric assumptions used in the main analysis are sufficient but not necessary conditions for the main results in the paper. The panels in Figure B12 report transition dynamics for these different sets of parameters. We can see that the changes in the composition of transactions and the fraction of renters are qualitatively analogous to those reported in Figure 10 in the text for config. I and II. The case for config. III is similar, but the transition in renting and transactions begins in the period *after* the shock arrives.

Figure B12: Transitions after Credit Shock
Alternative Parameters

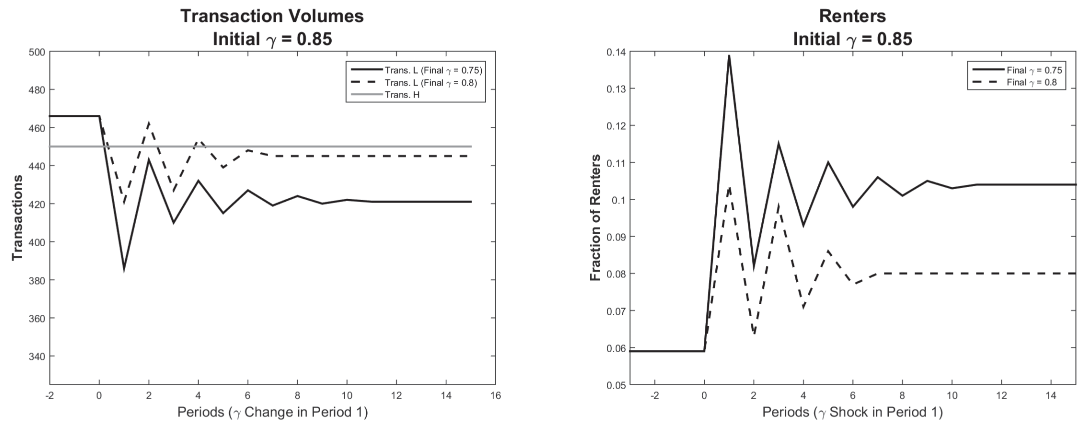
Case I



Case II



Case III



Note: **Left-panel** represents the time series of transaction volumes for H and L type dwellings. The horizontal axis represents time, and the vertical axis represents number of sales. Gray line corresponds to tr_H, and black lines correspond to tr_L. **Right-panel** represents the time series for the fraction of renters, represented in the vertical axis. Parameters and income distributions for the three cases reported in Table B7.

Table B7: Numerical Analysis: Parameter Values

Parameters	v_L	v_H	μ	S_L	S_H	r	γ_{i}	γ_{f1}	γ_{f2}
Config. I	200	280	0.5	1050	750	0.01	0.8	0.75	0.7
Config. II	200	280	0.5	1050	750	0.025	0.8	0.75	0.7
Config. III	200	280	0.5	1050	900	0.01	0.8	0.775	0.75

Income Distributions	Config. I	Config. II	Config. III
Period 1	$U[0.6, 1.5]$	$0.9 \times Beta[1.5, 1.5] + 0.6$	$4 \times Beta[2, 2] + 2$
Period 2	$U[1, 5]$	$6 \times Beta[1.5, 1.5] + 1$	$17.5 \times Beta[2, 2] + 2.5$
Period 3	$U[1, 6]$	$6 \times Beta[1.5, 1.5] + 1$	$17.5 \times Beta[2, 2] + 2.5$
# of Households (born in t)	1000		

Note: Parameters and income distributions for numerical analysis. Parameter γ_{i}, represents initial maximum LTV ratios, γ_{f1} indicates final γ after a moderate reduction, and γ_{f2} indicates final γ after a large reduction.

Appendix C - Data Sources

- The transactions data is made available by the **Land Registry**. As required by this government body I cite: Data produced by Land Registry ©Crown copyright 2015.

- Labour market outcomes at the local authority and regional level where obtained from the **Annual Population Survey** and the **Annual Survey of Hours and Earnings**.

- I have also used information from the **Wealth and Assets Survey**. Office for National Statistics. Social Survey Division, Wealth and Assets Survey, Waves 1-3, 2006-2012 [computer file]. 3rd Edition. Colchester, Essex: UK Data Archive [distributor], October 2014.

- Information for housing tenure at the unit level has been obtained from the **English Housing Survey**. Department for Communities and Local Government, English Housing Survey: Housing Stock Data. 4th Edition. Colchester, Essex: UK Data Archive [distributor], March 2013.

- **Internal migration** estimates were obtained fr the Office of National Statistics.

- Data from the Council of Mortgage Lenders was obtained from tabulations present in the CML's regular bulletins.

- Data on credit conditions during this period was obtained from the Credit Conditions Survey published quarterly by the Bank of England.

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