Very Long-Run Discount Rates

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Abstract

We provide direct estimates of how agents trade off immediate costs and uncertain future benefits that occur in the very long run, 100 or more years away. We exploit a unique feature of housing markets in the U.K. and Singapore, where residential property ownership takes the form of either leaseholds or freeholds. Leaseholds are temporary, pre-paid, and tradable ownership contracts with maturities between 50 and 999 years, while freeholds are perpetual ownership contracts. The difference between leasehold and freehold prices reflects the present value of perpetual rental income starting at leasehold expiry, and is thus informative about very long-run discount rates. We estimate the price discounts for varying leasehold maturities compared to freeholds and extremely long-run leaseholds via hedonic regressions using proprietary datasets of the universe of transactions in each country. Agents discount very long-run cash flows at low rates, assigning high present values to cash flows hundreds of years in the future. For example, 100-year leaseholds are valued at 10% to 15% less than otherwise identical freeholds, implying discount rates of below 2.6% for 100-year claims. Given the riskiness of rents, this suggests that both long-term risk-free discount rates and long-term risk premia are low. We show how the estimated very-long run discount rates are informative for climate change policy.

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Long-run discount rates play a central role in economics and public policy (Cochrane, 2011). For example, much of the debate around the optimal response to climate change centers on the trade-off between the immediate costs and the very long-term benefits of policies that aim to reduce global warming (Nordhaus, 2006; Weitzman, 2007; Barro, 2013; Pindyck, 2013). Similar cost-benefit analyses are required of all U.S. government agencies prior to proposing and adopting regulation.

Unfortunately, there is little direct empirical evidence on how households discount payments over very long horizons, because of the scarcity of finite, long-maturity assets necessary to estimate households' valuation of very long-run claims. For regulatory action with "intergenerational benefits or costs," the U.S. Office of Management and Budget therefore recommends a wide range of discount rates (1% - 7%), lamenting that while "private markets provide a reliable reference for determining how society values time within a generation, for extremely long time periods no comparable private rates exist."

We provide direct estimates of households' discount rates for payments very far in the future. We exploit a unique feature of residential housing markets in the U.K. and Singapore, where property ownership takes the form of either very long-term leaseholds or freeholds. Leaseholds are temporary, pre-paid and tradable ownership contracts with maturities ranging from 50 to 999 years, while freeholds are perpetual ownership contracts. The price difference between leaseholds and freeholds for otherwise identical properties captures the present value of perpetual rental income starting at leasehold expiry and is thus informative about households' discount rates over that horizon.

Our empirical analysis is based on proprietary information on the universe of residential property sales in the U.K. (2004-2013) and Singapore (1995-2013). These data contain information on transaction prices, leasehold terms and property characteristics such as location and structural attributes. We estimate long-run discount rates by comparing the prices of leaseholds with different maturities to each other and to the price of freeholds across otherwise identical properties. We use hedonic regression techniques to control for possible heterogeneity between leasehold and freehold properties. This allows us to identify price discounts associated with differences in lease length. We find that 100-year leaseholds are valued 10-15% less than otherwise identical freeholds; leaseholds with maturity of 125 to 150 years are valued 5-8% less than freeholds. There are no price differences between leaseholds with maturities of more than 700 years and freeholds. Our results suggest that households apply annual discount rates of below 2.6% to payments more than 100 years in the future.

While these housing markets provide an important setting for understanding very long-run discount rates, they are not frictionless markets. We, therefore, address a number of possible concerns that the observed price differences between leaseholds of different maturity and freeholds might not only be driven by the different duration of the claims, but also by other differences between the two contracts or frictions specific to housing markets. We show that the empirical results are consistent across the U.K. and Singapore, two housing markets with otherwise very different institutional settings. In addition, we provide direct evidence that the leasehold discounts are not related to either systematic unobserved structural heterogeneity across different properties, differences in the liquidity of the properties or a different clientele for the different ownership structures, and are unlikely to be explained by contractual restrictions in leasehold contracts.

We first address the concern that our estimated price discounts are driven by systematic differences in unobserved property characteristics. To do this, we analyze how annual rents differ across freehold and leasehold properties with different maturities. Conditional on observable property characteristics we find no differences in the rental prices of leasehold properties with different maturities and freeholds. This suggests that the observed sale price differences are not related to differences in the flow utility from these properties, but to the maturity of the contracts. Consistent with this, the absence of a price difference between leaseholds with 700 or more years remaining and freeholds provides further confidence that our hedonic control variables allow us to partial out all important sources of structural heterogeneity between leasehold and freehold properties.

We next consider whether covenants in leasehold contracts might explain the estimated price discounts. Since leaseholds with more than 700 years maturity trade at the same price as freeholds, we conclude that the price discounts between shorter leaseholds and freeholds are unlikely to be explained by fundamental differences in the general contract structure (e.g., a significant control premium or a duration-independent preference of households for freehold ownership), since these should show up along the entire term structure. This is confirmed by an analysis that estimates discounts only within leaseholds of different maturity, and finds them to be similarly large. We also show that our estimated price discounts persist even after controlling for the initial lease length of contracts, addressing concerns that restrictive covenants might be more prevalent for shorter maturity leaseholds. Finally, since most covenants restricting a short-maturity leaseholder would need to be passed on to possible renters of the property, the absence of differential rental prices for leaseholds of different maturity further confirms the absence of important restrictive covenants that differ by lease length.

We also document that price differences are not driven by differential liquidity of leasehold contracts with different maturities and freehold contracts, by showing that the time on market does not vary systematically across the term structure of remaining lease length. We then consider whether the presence of a different clientele for leasehold and freehold properties can explain the price differences, but find evidence that buyers of freehold and leasehold properties are essentially identical on observable characteristics. Finally, our estimates cannot be explained by potential financing frictions that might be important for short-maturity leasehold properties (50-80 years), since leasehold discounts remain substantial even for maturities of 200 years, for which the effects of potential financing frictions are more than a hundred years away.

To interpret the economic magnitude of the observed leasehold discounts and implied discount rates, we first analyze the predictions from a simple valuation model with constant discount rates across maturities; then, we consider the impact of risk and frictions in more general models. In the simplest constant-discount-rate model, rental income D_t grows deterministically at rate g and is discounted at a constant rate r. The prices for the the freehold P_t, and the T-maturity leasehold P_t^T are given by:

$$P_t = \frac{D_t}{r-g}; \qquad P_t^T = \frac{D_t}{r-g}(1 - e^{-(r-g)T}).$$

The first formula is the Gordon (1982) growth valuation for infinitely lived assets, the second formula corrects the freehold price for the shorter maturity of the leasehold to obtain the leasehold price.[1] In this model, the price discount between leaseholds and freeholds is:

$$Disc_t^T \equiv \frac{P_t^T}{P_t} - 1 = -e^{-(r-g)T}.$$

To understand the magnitude of the estimated discounts, we estimate unconditional expected housing returns r and rent growth g in the U.S., the U.K. and Singapore. Real rates of rent growth are low, about 0.5% a year. Expected real returns to housing are relatively high, between 7% and 9% a year, and primarily driven by high rental yields. Therefore, the constant-discount-rate model predicts that even with a conservative rate of return of 6.5% and optimistic rent growth of 2% the price discount of 100-year leaseholds relative to freeholds should be at most 1%. By contrast it is as high as 10-15% in the data.

This simple model highlights that the challenge for economic theory is to *jointly* rationalize a relatively high expected return to housing with the low discount rates necessary to match the observed discounts for long-dated leaseholds relative to freeholds. Intuitively, a model that can rationalize these valuation patterns requires a downward sloping term structure of discount rates for rents. Discount rates have to be sufficiently high in the short to medium run to contribute to high expected returns on housing, but

[1] In Section 4.1 we derive both formulas explicitly. Here we focus on the related intuition and the predictions for leasehold discounts.

sufficiently low in the long run to match the observed value of long-run cash flows. These patterns imply a low long-run risk free discount rate, and a low long-run risk premium for rents. Since rents are risky, they also imply a low long-run price of risk. We view this result as complementary to the recent and innovative contribution of Binsbergen, Brandt and Koijen (2012) and Binsbergen et al. (2013), who show that the term structure of equity discount rates is downward sloping for maturities up to 10 years.[2]

Beyond these insights for asset pricing theory, our results have implications for environmental economics. The literature on environmental policy has discussed extensively the importance of long-run discount rates in assessing the benefits of policies such as reducing carbon emissions (Gollier and Weitzman, 2010; Pindyck, 2013; Barro, 2013). For example, Stern (2007) calls for immediate action to reduce future environmental damage based on the assumption of very low discount rates, arguing that while agents discount the future over their lifetimes, they have an ethical impetus to care about future generations. This assumption has been criticized amongst others by Weitzman (2007) and Nordhaus (2006), who argued that private markets reveal discount rates well above zero. For example, Nordhaus (2006) points out that the private return to capital is 4-6%. Such estimates are based on claims to infinite streams of cash flows and, as such, are not directly informative of long-run discount rates. We contribute to this literature by providing direct empirical evidence on *long-run* discount rates. Our long-run discount rates of less than 2.6% are higher than those in the Stern report but substantially smaller than those suggested by the unconditional return to the capital stock or housing.

Our results are of direct relevance for real estate economics and the ongoing effort to understand house prices. We add to the recent research effort to understand the return properties of real estate (Flavin and Yamashita, 2002; Lustig and Van Nieuwerburgh, 2005; Piazzesi, Schneider and Tuzel, 2007; Favilukis, Ludvigson and Van Nieuwerburgh, 2010) by focusing on a previously unexplored aspect of real estate: the term structure of house prices. Finally, we also contribute to the recent literature on historical comparative analysis of asset price behavior during financial crises and rare disasters as in Bordo et al. (2001), Barro (2006), Reinhart and Rogoff (2009) and Schularick and Taylor (2012) by providing an extensive analysis of house price behavior during these events.

[2] Binsbergen, Brandt and Koijen (2012) discuss the challenges of leading asset pricing models to match a downward sloping term structure of discount rates. For risky cash flows the external habit formation model of Campbell and Cochrane (1999) and the long-run risk model of Bansal and Yaron (2004) produce an upward sloping term structure of discount rates, while the rare disaster model of Barro (2006) and Gabaix (2012) generates a flat term structure of discount rates. A nascent literature inspired by Binsbergen, Brandt and Koijen (2012) includes Belo, Collin-Dufresne and Goldstein (2012) and Boguth et al. (2012).

1 Housing Markets in the United Kingdom and Singapore

In this section we discuss the relevant institutional details of housing markets in the U.K. and in Singapore, highlighting the distinguishing characteristics of freeholds and leaseholds. Appendix A.1 provides detailed additional information.

1.1 Leaseholds and Freeholds in the U.K.

Property contracts in England and Wales come in two forms: permanent ownership, called a freehold, and long-duration, temporary ownership, called a leasehold. A leasehold is a grant of exclusive possession for a clearly defined, temporary period of time during which the tenant has the right to exclude all other people from the property, including the freeholder (Burn, Cartwright and Cheshire, 2011). At least 2.5 million properties in the U.K. are owned as leaseholds. Common initial leasehold maturities are 99, 125, 150, 250 or 999 years. During this period, ownership of the leaseholds entitles the lessee to similar rights as the ownership of the freehold, including the right to mortgage and rent out the property. Unlike for commercial leases, the vast majority of the costs associated with a residential leasehold come through the up-front purchase price; annual payments, the so-called "ground rents," are small to non-existent (see Appendix A.1), and do not significantly affect the prices paid for leaseholds. Leasehold properties are traded in liquid secondary markets, where the buyer purchases the remaining term of the lease.

Once the leasehold expires, the ownership reverts back to the freeholder. However, it is common for leaseholders to purchase leasehold extensions ahead of leasehold expiry. Over time, a number of laws described in Appendix A.1 have regulated the rights of leaseholders in the U.K. to extend their lease terms, and have codified the bargaining process between leaseholders and freeholders. For our sample period, the law states that leaseholders had the right to request a lease extension from the freeholder at a "fair price", and if leaseholder and freeholder cannot agree on such price, they can appeal to government-run leasehold valuation tribunal (LVT) with the power to set the prices for extensions.[3] In Section 6, we discuss the effects of LVT decisions and lease extension regulation on the interpretation of our results, and show that the particular institutional setting of the U.K. tends to balance the stronger negotiating power of freeholders with laws and court decisions that are biased towards the leaseholder.

In Section 2.1.5 and Appendix A.1.5 we discuss covenants in leasehold contracts (for example, restricting the type of commercial activity that can be operated on the land) as

[3] Since July 1, 2013, the functions of the Leasehold Valuation Tribunal were transferred to a newly created First-Tier Tribunal (Property Chamber).

another potential explanation of the price differences between leaseholds and freeholds. We provide empirical evidence that differential covenants across contracts are unlikely to explain the observed differences in prices between leaseholds and freeholds, and between leaseholds of different maturity. Finally, management fees and service charges that are sometimes levied on leaseholders for the maintenance of the property, and that are also discussed in the Appendix, primarily cover expenses also faced by freeholders, and do not significantly confound our analysis.

1.2 Leaseholds and Freeholds in Singapore

Residential properties in Singapore are also either sold as freeholds or leaseholds, where the latter have initial terms of 99 years or 999 years.[4] By far the largest freeholder is the government of Singapore, represented by the Singapore Land Authority (SLA). As in the U.K., there is a vibrant private secondary market for leaseholds, where buyers purchase the remaining term of the original lease.

At the expiration of the lease, the ownership interest reverts to the SLA. Leaseholders may apply for a renewal of the lease before expiration. The granting of an extension is decided on a case-by-case basis; considerations include whether the development is in line with the government's planning intentions, and results in land use intensification or the mitigation of property decay. Between 2007 and 2010 about 60% of lease extension applications were approved. If the extension is approved, the Chief Valuer determines the "land premium" that will be charged. Prior to 2008 an additional "building premium" was charged, based on the value the Chief Valuer puts on the building sitting on the land with an expiring lease and was payable if a lease extension was sought and the building not demolished. The new lease cannot exceed the original, and might be shorter if otherwise not in line with the Urban Redevelopment Authority's (URA) planning intention.

2 Empirical Analysis

The estimation of the relative prices of leaseholds and freeholds is potentially challenging because the underlying properties are heterogeneous assets. Since leasehold and freehold properties could differ on important dimensions such as property size and location, comparing prices across properties requires us to control for these differences. We use

[4]The earliest land lease was issued in 1826 with a term of 999 years. There are also other types of less common lease structures. The first are private developments with 103-year leaseholds sold on freehold land. In addition, in November 2012 a plot of land at Jalan Jurong Kechil was the first to be sold for residential development under an initial 60-year lease agreement; though houses built there do not yet appear in our data.

hedonic regression techniques (Rosen, 1974), which allow us to consider the variation in price over time and across lease terms for different properties while controlling for key characteristics of each property such as size, location and property age.

2.1 Analysis - United Kingdom

2.1.1 U.K. Residential Housing Data

We begin by analyzing data from England and Wales. We obtained transaction-level administrative data on all residential housing sales between 1995 and 2013 from the U.K. Land Registry. The data include the price paid as well as some characteristics of the house: whether the property is a flat or a house, the type of house (detached, semi-detached or terraced), the full address and a "new construction" indicator. In addition, the Land Registry has provided us with an indicator of whether the transaction was for a freehold or a leasehold property, as well as previously unexplored information on leasehold characteristics such as origination date and lease length. The leasehold associated with each transaction is the lease registered with the Land Registry at the time of the transaction.

Two limitations affect the combined transaction-leasehold data. First, until the Land Registry Act 2002, which was enforced from October 2003 (see Appendix A.1.2), leasehold registration was not mandatory for all leases, and leases were valid and enforceable even if they were not registered with the Land Registry. This limited the incentive to register a lease. Therefore, data before October 2003 are subject to measurement error because transactions that occurred before that date may have been erroneously associated with out-of-date leaseholds. For this reason, we focus our analysis on the period 2004-2013.

The second limitation is that the leasehold associated with each transaction in the Land Registry dataset is the lease registered with the Land Registry at the time of the transaction. This is not a problem for our analysis except when the freeholder and leaseholder agree to a lease extension, the timely registration of which is encouraged, but not required. A problem occurs if the lease extension happened before the sale transaction but is only registered afterwards. We have manually detected a number of such instances in a subsample of leasehold sale transactions. In those cases, the data erroneously reports the terms of the older and shorter lease, while the price paid pertains to the new and longer lease. This biases our analysis against finding a large price discount for short leases because a higher price (corresponding to a longer lease) would be mistakenly associated with a leasehold with fewer years remaining. When we can identify lease extensions (because we observe transactions that occur under both the old and the new lease), we observe that around 84% of extensions occur for leaseholds of less than 80 years remaining. We therefore focus on estimating price discounts for leaseholds with maturities above 80 years, where extensions are rare and which are particularly informative about very long-run discount rates.[5]

For a large subset of the properties, we have obtained proprietary property characteristics such as the number of bedrooms, bathrooms, the size of the house and the age of the property. These are collected by Righmove.co.uk from "for sale" listings and other data sources. We observe hedonic characteristics for approximately 80% of the properties transacting since 2004. For most properties, Rightmove also collects the "time on market" (i.e., the time between listing and sale), allowing us to test for possible liquidity differences between leaseholds of different maturities and freeholds. Finally, we have obtained from Rightmove "for rent" data for about $29,000$ flats that were listed in London in 2011 and 2012, allowing us to compare rental prices across leasehold and freehold properties.

2.1.2 U.K. Data: Summary Statistics

Our final dataset contains more than 8 million property transactions between 2004 and 2013. Table 1 provides key summary statistics for the U.K. transaction sample. Houses in the U.K. are mainly transacted as freeholds, with some very long leases and very few shorter leases. Flats are mainly traded as leaseholds. Since the market for flats and the market for houses are relatively segmented differ in their propensity to use freehold and leasehold contracts, we study them separately. In our main analysis we focus on flats, which have significant variation in terms of remaining lease length. Appendix A.3.1 shows that the estimated price discounts are, if anything, larger in the sample of housing transactions for which we have limited variation across contracts.

The top panel of Figure 1 shows the distribution of remaining lease lengths for flats at the time of sale. There are many transactions with remaining lease lengths below 300 years and above 700 years, allowing us to trace out the term structure of leasehold discounts across long horizons. To reduce noise in our estimation, we pool leaseholds into a number of buckets with similar remaining lease length, as shown in Table 1. The top panel presents the composition of our sample of flats, comprising almost 1.4 million transactions. About 3% of transactions are for freeholds, and 27% are for long leaseholds (700 or more years remaining). The rest of the transactions are for shorter-maturity leaseholds.

[5] We also exclude the 3.1% of transactions for properties for which we observe both a freehold and a leasehold transaction. This is because it is unclear whether transactions of the freehold cover the rents after leasehold expiry or the infinite flow of rents. In addition, when the same person purchases both the freehold and the leasehold, it is unclear what the division of price between the two titles captures. This also removes properties where the leaseholders have jointly purchased the freehold, and now own a "leasehold with a share of the freehold." We found these instances to be equally common across different remaining lease lengths.

While our dataset covers all of England and Wales, it is important to verify that all type of contracts are present in most locations. We focus on the variation in lease length within 3-digit postcodes; these relatively small geographical units correspond to the level of geographic fixed effects used in our hedonic analysis. For each of the 2,375 such postcodes in the U.K., we compute the fraction of transactions that occur with each lease length remaining as well as the fraction of freeholds. Appendix Table A.1 presents the distribution of the shares of freeholds and each type of leasehold across postcodes.[6] Overall, flats have significant variation across contract types (freehold vs. leaseholds), within leaseholds (by number of years remaining), and across geographic areas.

In the next section we study the price differences between freeholds and leaseholds of various remaining lease length, controlling for observable characteristics such as the number of bedrooms, bathrooms, property age and property size. Within each 3-digit postcode there are no systematic differences in observable characteristics across leaseholds with different remaining lease length; there are some small differences between freeholds and leaseholds.[7]

2.1.3 Price Variation by Lease Length Remaining - UK

In this section we estimate the relative prices paid for leaseholds of varying remaining duration and freeholds for flats in England and Wales. Given the support of the "remaining lease length" distribution we construct 5 buckets for different remaining *MaturityGroups*: 80-99 years, 100-124, 125-149 years, 150-300 years, and 700+ years. We then estimate regression (1) below. The unit of observation is a transaction i of a property in 3-digit post code h at time t. We assign each leasehold with remaining maturity T_i to one of the $MaturityGroup_j$ buckets depending on the number of years remaining on the lease at the point of sale. The β_j coefficients capture the log-discount of leaseholds with that maturity relative to otherwise similar freeholds.

$$log(Price_{i,h,t}) = \alpha + \sum_{j=1}^{5} \beta_j \mathbf{1}_{\{T_i \in MaturityGroup_j\}} + \gamma Controls_i + \xi_h \times \psi_t + \epsilon_{i,h,t} \quad (1)$$

[6] To visualize the geographic variation of freeholds and leaseholds, Appendix Figures A.2 - A.25 also provide maps of the shares of freeholds and leaseholds of different lease length remaining by postcode. The maps show significant geographic dispersion for freeholds and leaseholds in the case of flats.

[7] Appendix Figure A.26 plots the distribution of the residuals of a regression of these hedonic characteristic on year $\times$ 3-digit postcode fixed effects, the same fixed effects included in our main regression (1) below. For flats the distribution of these residuals is very similar across leaseholds with different maturity. For houses, instead, there are significant differences between the very long leaseholds (700+) and shorter leaseholds (<125 years remaining) in terms of observables, while freeholds and leaseholds look much more similar. This is further indication that short leaseholds in the UK market for houses are rare and potentially concentrated in non-representative properties.

We control for average prices in a property's geography by including 3-digit postcode by time of sale fixed effects. We also include dummy variables for whether the property is a new construction, as well as for the number of bedrooms, bathrooms, property condition, whether there is parking, and the type of heating. We further control for the size and age of the property in a flexible way by including dummy variables for 50 equally sized groups of these characteristics.[8] Standard errors are clustered at both the year and 3-digit postcode level, following the procedure in Petersen (2009).

Table 2 shows the results from regression (1) for flats; the different columns test the robustness of our estimates to different samples and specifications. In column (1) we control for the time of sale in the interacted fixed effects by including the month of sale, in column (2) by interacting the quarter of sale, and in column (3) by interacting the year of sale. In column (4), we interact all our controls with year dummies, to allow for time variation in the effect of property characteristics. In column (5) we report the results obtained by winsorizing prices at the 1% level to reduce the possible effect of outliers. In column (6), we report the results obtained using only flats with non-missing property characteristics. In column (7) we report the results excluding the London postal district.

The coefficients β_i of our baseline case, column (1), are also plotted in the bottom panel of Figure 1. Freeholds and leases with maturities of more than 700 years trade at approximately the same price: the coefficient on $\beta_{700+Years}$ is small and statistically indistinguishable from zero. This suggest that the present value of rents starting in 700 years is negligible. Leaseholds with shorter maturities trade at significant discounts to otherwise identical freeholds: leaseholds with 80-99 years remaining trade at an approximately 16% discount to freeholds; the discount decreases to 10% for leaseholds with 100 to 125 years remaining, 8% for 125-150 years remaining, and 3% for 150-300 years remaining.[9] The results are robust to the various specifications reported in Table 2.

The estimated price differences between leaseholds of different maturities and freeholds suggests that there is significant present value attached to rents 100 or more years in the future, and, therefore, relatively low discount rates applied to those rents. Before interpreting the results in terms of standard models of discount rates, we next explore some ex-ante plausible alternative interpretations of the estimated price discounts: the presence of unobserved structural heterogeneity in the properties sold, the impact of leasehold covenants, differential liquidity of leasehold and freehold properties, or a different clientele for these contracts.

[8] In all cases, observations with a missing characteristics are assigned a unique indicator variable. This means that we do not have to drop the observation from the dataset. As a robustness check, column (6) of Table 2 considers only properties with a complete set of observable characteristics.

[9] The percentage discount is calculated as $1 - e^{\beta}$.

2.1.4 Unobserved Structural Heterogeneity

An important identifying assumption of our analysis is that after controlling for observable characteristics, leasehold and freehold properties are similar except for the remaining maturity of the claim. In particular, our interpretation requires that the flow utility from these two properties is the same. A first piece of evidence that our hedonic regression allows us to control for all important structural differences is that there is no observed price difference between 700+ year leaseholds and freeholds.

In addition, while an econometrician is unable to observe all characteristics that might affect the flow utility from a property (such as some dimensions of "quality"), to the extent that these characteristics affect the prices paid for leaseholds and freeholds they also affect the annual market rents for these properties. Conversely, if our controls correctly capture all fundamental sources of systematic heterogeneity across leasehold and freehold properties, rents should not differ significantly between leaseholds and freeholds.

To test this, Rightmove.co.uk has provided us with a sample of around 29,000 rental listing prices for flats with a full set of property characteristics listed in London during 2011 and 2012. The top panel of Figure 2 shows the price discounts in "for sale" transactions for our full sample as well as the subsample for which we observe rental prices; this regression is identical to Column (1) in Table 2. Price discounts are very similar in both samples, suggesting our sample is representative on this important dimension.[10]

In Columns (1) - (3) of Table 3, we estimate different specifications of regression (1) using the log of annual rents as the dependent variable. There is no significant and systematic difference between rental rates of freeholds and leaseholds of different maturity. The bottom panel of Figure 2 shows the rental discounts graphically. These results provide support to the assumption that our controls are correctly capturing the main heterogeneity across properties, and no significant unobserved quality is left to confound the estimation of the maturity discount between leaseholds and freeholds.

2.1.5 Possible Impact of Leasehold Covenants or Contract Structure

A second alternative interpretation of the results presented above is that buyers might perceive a qualitative difference between owning a leasehold and owning a freehold, either because of restrictions on leaseholders or because of a psychological preference for freehold ownership that goes beyond the desire to appropriate the infinite stream of rents.

[10] Note that in the rental sample we have dramatically less power to identify the leasehold discounts. Our identification comes from within-postcode within-month variation, and while we observe all 29,000 rental prices within 2 years, sale transactions of those properties potentially date back to 2004. Therefore, we have few of these 29,000 properties that transact in the same month and postcode, making the estimates somewhat more noisy.

To show that this is not the case, we repeat the analysis for flats excluding freeholds, using only within-leasehold variation to estimate the price discounts. The excluded category are the 700+ year leaseholds. The estimated price discounts between leaseholds with 80-99 years remaining relative to leaseholds with 700+ years remaining confirm our interpretation of significant present value attached to cash flows occurring in the very-long run (see Appendix Table A.3 and the top panel of Appendix Figure A.28 for details).

This analysis, however, does not yet rule out that covenants might be more restrictive on shorter leases, which might affect the relative valuation of leaseholds of different remaining maturity. However, the differential prices by remaining lease length persist even after controlling for initial lease length fixed effects. To show this, we run regression (1) while including fixed effects for the 10 most common initial lease lengths (92% of transactions are for properties with one of these initial lease lengths), as well as an indicator for whether transactions occur as a new contract is started. We include fixed effects for initial lease lengths of 99, 120, 125, 150, 155, 199, 200, 250, 800 and 999 years.

Table 4 shows the results. Since initial lease length and remaining lease length at transaction are highly collinear, the estimates in this regression are relatively more noisy. Nevertheless, a clear pattern between remaining lease length and price of the leasehold remains. In particular, the discount for houses with 80 to 100 years remaining drops from about 16% to 13%, and part of the discount is instead attributed to the property being (in most cases) a sale of a 99-year contract. The discount for transactions with 100-124 years remaining is essentially the same as in our main regression, about 10%, and the 125 year contract indicator does not contribute to the discount for these properties. This test suggest that covenants are unlikely to be the explanation for the estimated discounts: if shorter leases had significantly more restrictive covenants we would expect the initial-lease-length fixed effects to capture all the variation in estimated discounts across leaseholds with different remaining maturity.

We also note that to the extent that restrictive covenants influence the flow utility from the property (for example, because they require a certain configuration of the flat), these restrictions should be passed onto renters of the property. The absence of differential rents across leases of different maturity makes it unlikely that there are significant differences in restrictive covenants.[11]

[11] In fact, in discussions regarding appropriate comparables for valuation purposes in cases before the Leasehold Valuation Tribunal, the leasehold covenants are very rarely discussed as a significant source of heterogeneity across contracts.

2.1.6 Differential Market Liquidity

A third alternative interpretation might be that while leasehold and freehold properties deliver the same flow utility, they could be differentially liquid in the resale market. To test whether this hypothesis explains the estimated price discounts, Rightmove provided us with for-sale listings information from about 2.4 million transactions of flats and houses. For these transactions we calculate the time between first listing and sale, i.e. the time on the market, which provides a good proxy for the liquidity of the asset. If it took significantly longer for owners of leaseholds to find buyers (and this problem got worse as the lease length declined), this could explain some of the observed estimates.

To test whether liquidity differs by duration of the lease, Columns (4) to (6) of Table 3 repeat the analysis of regression (1) using time on the market as the dependent variable. The results show that leaseholds tend to stay a modest 3-6% longer on the market than freeholds, relative to a mean of about 160 days. Importantly, there is no pattern between remaining lease length and time on market that could explain the significant discounts we found in comparing short and long leases. The highest time on market is observed for leasehold of 150-300 years remaining, followed by the groups 125-149, 80-99, 100-124 and 700+. Differences in liquidity are therefore unlikely to explain our results.

2.1.7 Market Segmentation

We observe no characteristics of the buyers or sellers in our transaction sample. Consequently, there might be a concern that the clientele for leasehold and freehold properties is different, which could explain the price differences that we observe. To address this concern, we analyze data from the Survey of English Housing (SEH), an annual household-level survey conducted between 1994 and 2008 that allows us to compare characteristics of owners of freeholds and leaseholds.

We focus on the sample of 201,933 owner-occupiers. Table 5 shows the results for important household characteristics. In columns (1) and (2) we show the mean and standard deviation of the outcome variable. Column (3) shows the unconditional difference between households owning leaseholds and freeholds: households owning leaseholds have, on average, £48 less weekly income. However, we showed above that leaseholds and freeholds pertain to different property types in general, something we control for in our hedonic analysis. Since we would expect buyers of flats (which are predominantly leaseholds) to be different to buyers of houses (which are predominantly freeholds), we analyze the differences in buyer characteristics conditional on our observables. To do so, we employ regression (2) which controls for property type by region fixed effects in analogy to the hedonic pricing regression (1). Geographic controls here are more coarse than in previous sections because the SEH only reports 354 unique local authority codes.

$$Outcome_i = \alpha + \beta Leasehold_i + \zeta X_i + \phi_{PropertyType \times Region} + \varepsilon_i. \tag{2}$$

Columns (4) and (5) in Table 5 show the point estimates and clustered standard errors for β, with column (5) controlling for other property characteristics that are observed in both the SEH and the transaction dataset, such as the number of rooms and the property age. The evidence shows that the households owning freeholds and leaseholds are very similar. For example, the weekly income of households owning leasehold properties is between £3 less and £8 more than the income of households owning freeholds; this difference insignificant and small relative to a sample mean and standard deviation of £350 and £450, respectively. The lack of major differences across buyers conditional on our observables makes it unlikely that our results are driven by clientele effects related to, for example, differential bequest motives.

2.2 Analysis - Singapore

2.2.1 Singapore Residential Housing Data

We have obtained transaction-level price data for all private residential transactions in Singapore from the Urban Redevelopment Authority. We do not use transaction prices for property sales by the Housing Development Board (HDB), which usually happen at below-market value (see Appendix A.2). We observe approximately 380,000 private market arms-length transactions between 1995 and 2013. For each transaction there is information on the transaction price and date, the lease terms, property characteristics and the precise location of the property. Table 6 provides an overview of the transaction sample used in the regressions. There are between 10,000 and 40,000 transactions per year. Between 30% and 60% of all private transactions each year are recorded for freehold properties. Initial lease lengths for leaseholds are generally 99 years or 999 years. We observe substantial dispersion in the lease length remaining at the time of sale. Figure 3 plots the remaining lease length at sale of leaseholds with initially 99 years (left panel) and initially 999 years (right panel). There are no transactions of leaseholds with 100 to 800 years remaining on the lease, and very few transactions with lease lengths less than 70 years.

For Singapore we observe fewer hedonic characteristics than for the U.K.; the primary characteristics are property size, development size and property age. In Appendix Figure A.27 we analyze whether properties with different remaining lease length differ along those dimensions in a systematic way, by plotting the residuals of a regression of the hedonic characteristics on property type × title type × 5-digit postcode fixed effects, similar to the fixed effects included in regression (3) below. We find that conditional on those fixed effects there is no systematic difference in property characteristics by lease length remaining, except that older properties, unsurprisingly, tend to transact with fewer years remaining on the lease.

2.2.2 Price Variation by Lease Length Remaining - Singapore

To analyze the relative price paid for leaseholds and freeholds we run regression (3) below. The unit of observation is a property i of type h (e.g., apartment, condominium, detached house, executive condominium, semi-detached house and terrace house), of title type s (either "strata" or "land"),[12] in geography g, sold at time t. For leaseholds the variable T_i captures the number of years remaining on the lease at the time of sale. We split the 99-year leases into four buckets with different groups of lease length remaining (50-70 years, 71-85 years, 86-90 years, 91-95 years and 96-100 years). We also include a dummy variable for all 999-year leases, all of which have at least 800 years remaining when we observe the transaction. The excluded category are the freeholds. The key dependent variable is the log of the price paid in the transaction.[13]

$$\ln{(Price)}_{i,h,s,g,t} = \alpha + \sum_{j=1}^{J} \beta_j \mathbf{1}_{\{T_i \in MaturityGroup_j\}} + \gamma Controls_{i,t} + \\ + \xi_h \times \rho_s \times \phi_g \times \psi_t + \epsilon_{i,h,s,g,t} \tag{3}$$

The results from this regression are shown in Table 7. In column (1) we control for 5-digit postcode by property type by title type by transaction quarter fixed effects. Beyond these $94,700$ fixed effects, our other control variables include property age, size and type, as well as the total number of units in a development. Standard errors are double clustered by 5-digit postcode and by year.

The results are consistent with our findings for the U.K.: the price paid for freeholds and otherwise similar leaseholds with more than 800 years remaining is economically and statistically identical. Leases with durations of 100 years or less sell at a significant dis-

[12] Residential properties in Singapore are classified into land or strata titles. Land title properties occupy land that is exclusive to the owner (e.g., a detached house), whereas a strata title comprises units in cluster housing (e.g., an apartment). Owners of strata properties enjoy exclusive title only to the airspace of their individual unit. The land that the development is built on is shared by all the owners of the project, based on the share of the strata title unit owned by each owner.

[13] In order to avoid our results being primarily driven by extreme outliers such as luxury condominiums, we winsorize the price at the 1% level. This adjustments has little effect on the estimated coefficients.

count to otherwise identical freeholds. For example, a lease with 96-100 years remaining maturity trades at an 11.8% discount, a lease with 71-85 years remaining maturity trades at a 24% discount.[14] In column (2) we control for the transaction month rather than the transaction quarter. This is to address possible concerns that leaseholds and freeholds might transact at different times in the quarter, which, combined with aggregate market price movements over time, could confound our estimates. While this increases the total number of fixed effects to approximately $98,000$ and $140,000$ respectively, the estimated discounts across all maturities remain the same in both specifications. The bottom panel of Figure 3 plots the coefficients β_j from regression (3) as in column (2) of Table 7.

In column (3) we restrict transactions to those where the buyer is not the HDB. The results are essentially unchanged, suggesting that sales to the HDB generally happen at market value. In column (4), rather than controlling for the of the property age directly, we only focus on the sale of newly-built properties. The estimates for 95-99 year leases are unaffected. For leases with shorter maturities the estimates of the discount increase somewhat. However, since most leases get topped up to 99-years when the property gets rebuilt, there are few observations to estimate the discount of new properties with 80 years lease length remaining. In column (5) we restrict our analysis to strata properties, which comprises the majority of all title types; in column (6) we restrict the analysis to land titles. 999 year leaseholds and freeholds trade at the same price. There are very few land title properties trading on 99 year leases, making it hard to estimate the lower end of the term structure of leasehold discounts. Nevertheless, while the estimates are very noisy (and there are not sufficient data to estimate every bucket), the point estimates for the land title and strata regressions are similar.

As in the analysis of the U.K. data, there are potential concerns that contractual differences between leasehold and freehold properties might contaminate our analysis. To address this concern, we re-run regression (3) restricting our sample to leaseholds with an initial lease length of 99 years (this analysis is similar to Section 2.1.5, since it keeps initial contract structure constant). The excluded category is leases with 96-100 years remaining. The results are consistent with our findings for the U.K. as well as the analysis comparing leaseholds to freeholds in Singapore. Across all specifications, leaseholds with 71-85 years remaining trade at a 27-29% discount relative to leaseholds with 99 years remaining. See Appendix Table A.4 and the bottom panel of Appendix Figure A.28 for details.

[14] The regression has a high adjusted R^2 of above 95%. This suggests that there remains no significant variation in prices that is not explained by our control variables, and that our discounts are thus unlikely to be driven by unobserved heterogeneity between freehold and leasehold properties. The adjusted R^2 remains at 95% if we exclude those instances where we only observe one transaction for a particular fixed effect, in which the fixed effects perfectly explains the transaction price. This is consistent with properties in Singapore being very homogeneous, in particular conditional on our tight geographic fixed effects.

3 Housing Risk and Returns, and Rent Growth Rates

As discussed in the introduction, understanding the price discounts estimated in the previous section requires information about the rate of return on housing and the growth rate of rents (r and g, respectively). In this section we discuss empirical estimates of r and g as well as historical evidence on the riskiness of housing.

We estimate the expected return to housing and the growth rate of rents using several methodologies and sample periods. We summarize our findings in Table 8 and leave the details of the methodologies to Appendix A.3. The top panel presents the estimated average housing returns for the U.K. and Singapore, as well as the U.S.[15] These are real net returns to housing because they account for maintenance, depreciation, taxes and inflation. Average real net returns are in the range $8-10\%$ for all countries considered. To be conservative, we choose a baseline estimate of $r = 6.5\%$, almost two percentage points below the lowest return observed in any country in our sample. This benchmark is consistent with estimates for the U.S. in Flavin and Yamashita (2002), who find a real return to housing of 6.6%, and Favilukis, Ludvigson and Van Nieuwerburgh (2010), who find a real return of 9-10% before depreciation and property taxes. The bottom panel of Table 8 shows that average real rental growth rates are approximately 0.5% in all three countries. To be conservative, we choose a baeline estimate $g = 0.7\%$ which is the maximum observed value in the data.[16]

Our estimates of average returns to housing imply a positive housing risk premium. Intuitively, houses are risky because they have low payoffs during bad states of the world such as wars, financial crises, natural disasters, and epidemics. We formalize this intuition by analyzing how house prices react during such events, as well as estimating their average correlation with consumption and personal disposable income.

The top panel of Figure 4 shows the average reaction of house prices to financial (banking) crises. The analysis is based on dates of financial crises in Schularick and Taylor (2012), Reinhart and Rogoff (2009) and Bordo et al. (2001) for 21 countries for the period 1870-2013 and on our own dataset of historical house price indices for these countries.[17]

[15] U.S. housing returns, while not the focus of this paper, provide a useful benchmark because they have been the subject of an extensive literature (Gyourko and Keim, 1992; Flavin and Yamashita, 2002; Lustig and Van Nieuwerburgh, 2005; Piazzesi, Schneider and Tuzel, 2007).

[16] Overall, our estimates are consistent with the notion that average house price growth over long periods of time is relatively low and the key driver of real housing returns is the high rental yield (see Shiller, 2006). Our estimated average capital gains are positive but relatively small despite focusing on samples and countries that are often regarded as having experienced major growth in house prices. For more evidence on low average real house price appreciation and low real rent growth rates see Appendix A.3.3.

[17] Appendix A.3.3 provides details of the crises dates and the house price series. The raw data are available on the authors' websites. The closest paper is Reinhart and Rogoff (2008) who analyze real estate prices for 16 countries for 18 crises occurring in the period 1974-2008. We analyze real estate prices in 21 countries

House prices rise on average in the 3 years before the crisis, achieve their highest level just before the crisis (here normalized as time zero and a house price level of 1), and then fall by as much as 7% in real terms in the 3 years that follow the onset of the crisis. The fall in house prices during crises contributes to making housing a risky asset. Similarly, the bottom panel of Figure 4 shows the average behavior of house prices during the rare disasters of Barro (2006) and Barro et al. (2008). The blue dotted line tracks the level of consumption: consumption falls for 3 years ahead of achieving its lowest point (the trough in consumption is normalized here to be time zero) and then recovers in the subsequent 3 years. The green solid line tracks the house price level: house prices fall together with consumption in the first 3 years of the disaster but then fail to recover, as consumption does, during the following 3 years. The fall in house prices during these rare disasters contributes to the riskiness of housing. The consumption disaster dates for the 21 countries included in our historical house price index dataset are those defined by Barro et al. (2008). In Appendix A.3.4 we show that this general pattern of house price decline during crises is also observable for the U.K. and Singapore, and provide further evidence that house prices collapse during crises and wars.

We also investigate the average correlation between consumption and house prices over the entire sample rather than just during crisis periods. Table 9 reports the correlation, over the entire sample and for each country, of house prices changes with consumption changes. The correlation is always positive for all 21 countries, except for France (-0.05), and often above 0.5. The estimated positive correlation between house prices and consumption reinforces the evidence that housing is a risky asset: it has low payoff in states of the world where consumption is low and marginal utility is high.[18]

Despite extensive efforts to collect an extensive database, our results are still limited by the relatively small number of crises for which house price data are available and by the lower quality of house price time series before 1950. Nevertheless our results suggest that housing is an asset with risks broadly consistent with its estimated expected return.[19]

for 44 crises and 16 rare disasters occurring in the period 1870-2013.

[18]Appendix A.3.3 provides a similar analysis with a balanced panel of 22 countries for the period 1975-2012 focusing on the correlation between house price changes and changes in personal disposable income. We find all estimated correlations to be positive.

[19]In fact, our results are likely to underestimate the riskiness of housing because of three effects: index smoothing, declining rents during bad times, and destruction of the housing stock during wars and natural disasters. (1) House price indices are generally smoothed and therefore underestimate the true variation in house prices. (2) We only analyzed the behavior of house price changes (capital gains) and have not considered the behavior of rents (dividends). For the two countries for which high-quality long-history time series of rental indices are available, France for the period 1949-2010 and Australia for the period 1880-2013, we find rent growth to be positively correlated with consumption growth (0.36 and 0.15 respectively). (3) A substantial part of the housing stock tends to also be destroyed during wars. Therefore, the return to a representative investment in housing would be lower than the fall in index prices because it would

We summarize our results in the following stylized facts: (i) housing is a risky asset that performs poorly during bad economic events, (ii) correspondingly it has expected returns of at least 6.5% per year; (iii) real rent growth rates are low, at about 0.5% per year.

4 Discussion and Interpretation

Section 2 presented new facts about the relative pricing of freeholds and leaseholds of different maturities. Leaseholds with over 700 years of maturity trade at the same price as freeholds for otherwise identical properties. For leaseholds with shorter maturities the price discounts range from 10-15% at 80-100 years remaining to 5-8% at 125-150 years.

In this section we introduce a simple pricing model with constant discount rates to rationalize these price differences. This basic model illustrates that the main challenge our empirical results present for economic theory is to *jointly* match the significant leasehold discounts and the high average return to housing estimated in Section 3. We generalize this result by deriving a simple formula that relates the price discounts to risk-adjusted long-run discount factors and the expected appreciation of the freehold over the maturity of the leasehold. We use this formula together with our estimates of long-run capital gains on housing and information from the U.K. real gilts yield curve to relate the leasehold discounts to long-run risk premia. The data are consistent with low long-run risk-free rates and low long-run risk premia.

4.1 Constant Discount Rates and Leasehold Discounts

We start by considering the simple constant-discount-rate extension of the classic valuation model of Gordon (1982) that we discussed in the introduction. We assume that rents (cash flows) arising in each future period are discounted at a constant rate r, so that the t-period discount function is e^{-rt}. We also assume that rents are expected to grow at a constant rate g, so that expected rents follow: $E_t[D_{t+s}] = D_t e^{gs}$.[20] In this model, a claim to the rents for T periods, the T-maturity leasehold, is valued at:

$$P_t^T = \int_t^{t+T} e^{-r(s-t)} D_t e^{g(s-t)} ds = \frac{D_t}{r-g}(1 - e^{-(r-g)T}). \tag{4}$$

incorporate the physical loss of part of the asset.

[20]Technically, g is the sum of the expected growth rate of rents and a Jensen inequality term. Given the low variance of rent growth and in the interest of intuitive results, we ignore the latter term and refer to g as the expected growth rate of rents.

Correspondingly, the infinite maturity claim, the freehold, is valued at: $P_t = \lim_{T\to\infty} P_t^T = \frac{D_t}{r-g}$. This valuation formula for infinite maturity claims is the classic formula by Gordon (1982). The price discount for a T-maturity leasehold with respect to the freehold is:

$$Disc_t^T \equiv \frac{P_t^T}{P_t} - 1 = -e^{-(r-g)T}. \tag{5}$$

For any given maturity, the price discount decreases (in absolute value) the higher the discount rate r and the lower the growth rate of rents g. The first effect occurs because a higher discount rate reduces the present value of rents occurring far into the future. The second effect occurs because a higher growth rate of rents increases the actual rents occurring in the future.

At the estimated benchmark values of $r = 6.5\%$ and $g = 0.7\%$, the constant-discount-rate model implies a leasehold discount at 100 years of $Disc^{100} = -e^{-0.058*100} = -0.3\%$. In other words, the 100-year leasehold would be valued only 0.3% less than the freehold. The discount we find in the data is 10-15%, orders of magnitudes higher. More generally, the white bars in Figure 5 compare the logarithmic discounts obtained under our baseline calibration for different leasehold maturities with those observed in the data for the U.K. and Singapore (data is in black bars). The 700+ year leaseholds are valued at essentially a 0% discount to freeholds both in the data and in the model. However, the model cannot match the discounts observed for leaseholds with maturities of 300 years or less. Intuitively, a model of exponential discounting assigns essentially zero present value to cash flows occurring 100 or more years into the future when discounting at an effective rate $(r - g)$ of 6% or more. This intuition is robust to even more conservative calibrations of r and g. We evaluate a "high rent growth rate" scenario by setting $g = 2\%$,[21] and a "low expected returns" scenario with $r = 5.5\%$, significantly less than our lowest estimate. Figure 5 shows that the discounts increase modestly even under these conservative scenarios and that the model cannot match the data, especially at longer horizons.

Long-run discounts could be matched by an (unrealistic) calibration with a constant net discount rate of $r - g = 1.9\%$. This calibration would not be consistent with the high

[21]Rents are unlikely to grow at a faster rate than consumption in the long run, since this would imply that over time a larger and larger fraction of consumption expenditures would be devoted to housing. One might conjecture that "super-star" cities like Singapore or London might experience even higher rent growth in the future (Gyourko, Mayer and Sinai, 2006). However, the past low growth rate of rents occurred in a period when London and Singapore were already major capitals of the world. This makes it unlikely that the observed discounts could be explained by the possibility of sufficiently high rent growth to induce g to be very close to r for a long period of time (Pástor and Veronesi, 2003). In addition, Section 2 showed that leasehold discounts for the U.K. are very similar outside of London. Finally, even if rent growth increased significantly, since prices and rents are cointegrated, in the long run the higher rent growth rates would correspond to higher capital gains, leaving $r - g$ unaffected.

average return to housing and the low growth rate of rents observed in the data. The simple constant-discount-rates model thus highlights the challenge for economic theory posed by our results: to *jointly* rationalize both a high expected return to housing and the low long-run discount rates necessary to match the observed discounts for long-dated leaseholds relative to freeholds.

4.2 General Formula for Leasehold Discounts

We now derive a more general formula that links the price differences between freeholds and leaseholds to risk-free discount rates, risk premia, and the capital appreciation of the freehold. Intuitively, the price difference between a freehold and a T-maturity leasehold is the present value at time t of a freehold starting at time T. We can compute this present value by applying a simple valuation formula: $P_t - P_t^T = \frac{E_t[P_T]}{R_{t,t+T}}$, where $R_{t,t+T}$ is the total discount rate. We obtain percentage discounts by dividing both sides by P_t:

$$Disc^T = -\frac{E_t[P_T]/P_t}{R_{t,t+T}} = -\frac{E_t[P_T]/P_t}{R^f_{t,t+T} + RP_{t,t+T}}, \tag{6}$$

where $R^f_{t,t+T}$ is the discount rate appropriate for a risk-free claim and $RP_{t,t+T}$ is the risk-premium adjustment due to the riskiness of rental income. This shows that the leasehold discounts estimated in Section 2 are related to two basic forces: the expected capital appreciation on the freehold (the numerator), and the discount factor (the denominator). The discounts are bigger the more households expect the price of the freehold to increase over the length of the leasehold. This is because the leaseholder does not benefit from these capital gains while the freeholder does. The discounts are also bigger the lower the discount factor, since this attaches higher present value to future rents.[22]

To interpret Equation (6), we combine our estimates of the leasehold discounts $Disc^T$ from Section 2 with estimates of long-run capital gains on housing ($E_t[P_T]/P_t$) from Section 3 and estimates of long-run risk-free discount rates ($R^f_{t,t+T}$) from the real U.K. gilts yield curve. The real yield curve is flat on average for maturities between 1 and 25 years with an average real yield of 1.4% for the period 1998-2013. The Bank of England also made available a 40 year real yield for the period 2006-2013; the average 40 year real yield during this period was 0.4%.[23] This latter estimate should be interpreted with caution not

[22]Notice that we can recover the discounts implied by the Gordon growth model in equation (5) by substituting the model's assumptions in equation (6): $R^f_{t,t+T} + RP_{t,t+T} = e^{-rT}; \quad E_t[P_T]/P_t = e^{gT}$.

[23]The real yield curve is computed by the Bank of England and is available at `http://www.bankofengland.co.uk/statistics/Pages/yieldcurve/archive.aspx`. We are grateful to Zhuoshi Liu at the Bank of England for making the long-maturity average yield available to us.

only because of liquidity concerns but also because the period is dominated by the global financial crisis and the European sovereign debt crisis.[24] We conclude that the UK real yield curve is approximately flat on average for maturities between 1 and 25 years with a real yield of 1.4% and that there is some evidence for a mild downward slope at longer maturities with an an average 40 year yield below 1%.[25] Using a calibrated value of 1.4% across the term structure of risk-free discount rates, we can then decompose the total discount rate needed to match the leasehold discounts into the risk-free component $R^{f}_{t,t+T}$ and the risk premium $RP_{t,t+T}$. For example, if rents grow at a rate of 0.7% per year and prices grow in the long run at the same rate, the annualized risk premium for a 100-year claim $\frac{\ln(RP_{t,t+T})}{T}$ will be just above 2%.

Without further structural assumptions we cannot split the risk premium, $RP_{t,t+T}$, into components that captured the asset-specific quantity and economy-wide price of long-run risk. However, since rents and consumption are likely to be cointegrated, claims to long-run rents should be as risky as claims to long-run consumption (see Appendix A.3.3). In related evidence, Jeske, Krueger and Mitman (2011) show that the share of consumption expenditures on housing over total consumption in the U.S has been remarkably constant at 14.1% over the past 40 years.[26] Long-run rents in cities such as London or Singapore also carry substantial systematic risk, since they load heavily on the performance of the global economy; this is consistent with the high average returns to housing estimated in Section 3. This suggests the presence of substantial long-run risk for rents, and hence a relatively low price of risk is required to match our relatively low estimated risk premium.

[24] Appendix Figure A.36 plots the average shape of the real U.K. gilts curve for the period 1998-2013, as well as for two sub-periods: 1998-2007 and 2007-2013. The level of the yield curve shifted down during this latter period and the yield curve became hump-shaped.

[25] Our estimates of long-run discount rates provide further support for the volatility bounds on the permanent component of pricing kernels derived by Alvarez and Jermann (2005) not only via the direct observation of low U.K. 40-year real yields, but mostly by observing the discount rates for assets very far into the future, 100 or more years. Since housing is a risky asset, our estimated total discount rates provide an upper bound for the risk-free discount rates that Alvarez and Jermann (2005) are directly interested in.

[26] This evidence pertains to total rents including growth in the housing stock and size/quality adjustments. Since the housing stock grows and people over time live in bigger and better houses, the growth rate of rents for a typical property is below the growth rate of consumption. However, the quality/quantity adjustment, while it clearly affects the long-run growth rate, is less likely to affect the stochastic properties (risk) of rents.

5 Implications of the Findings

5.1 Matching Returns and Leasehold Discounts in Reduced-Form

We find our estimates to be consistent with a downward sloping term structure of total discount rates. Discount rates have to be sufficiently high in the short to medium run to contribute to high average expected returns on housing, but also sufficiently low in the long run to match the observed discounts applied to long-run cash flows. A convenient analytical functional form to match the downward sloping term structure of total discount rates is a mix of hyperbolic and exponential discounting. It is beyond the scope of this paper to provide a full model explaining where such discounting function might be coming from; here it is simply taken as exogenous.

We assume that the discount function follows: $R_{0,t} = \frac{e^{-\rho t}}{1+\kappa t}$, where $\rho > 0$ is the subjective discount rate associated with exponential discounting, $\kappa > 0$ is the hyperbolic parameter. If $\kappa = 0$ we recover exponential discounting at $e^{-\rho t}$, while if $\rho = 0$ we recover hyperbolic discounting at $\frac{1}{1+\kappa t}$. This mixed form of discounting tends to behave like hyperbolic discounting in the short run and like exponential discounting in the long run. The parameters ρ and κ should not be interpreted as deep primitives, but simply as convenient mathematical representations.[27] Since we are not aiming to decompose the total discount rate into the risk-free and risky subcomponents, we resume our assumption from Section 4.1 that rents grow at constant rate g.

In this set-up, the T-maturity leasehold is valued at: $P_0^T = \int_0^T \frac{e^{-(\rho-g)s}}{1+\kappa s} D_0 ds$. Appendix A.4.3 derives analytic expressions for the resulting value, as well as for the value of the freehold. Figure 6 shows the discounts implied by a calibration of this reduced-form hyperbolic-exponential model that at the same time matches the observed discounts of leaseholds of different maturities and the average return to housing. The calibration is obtained by setting κ to 12% and ρ to 1.42%. This calibration implies higher discount rates for short term than for long term cash flows.

To illustrate this property, we analyze the evolution of the per-period equivalent constant discount rate: $r_T \equiv \rho + \frac{\ln(1+\kappa T)}{T}$. For each maturity T, r_T is the constant discount rate that produces a total discount $R_{0,T}$ identical to the hyperbolic-exponential model. The bottom left panel of Figure 6 plots r_T, illustrating the dynamics that total discount rates of general equilibrium models would have to generate to match the data. The very short-run discount rate is $\rho + \kappa = 13.42\%$, the term structure is downward sloping, and

[27] That is: we are not assuming that agents have either hyperbolic or exponential discounting, but simply that, whatever the underlying true model might be, the equilibrium discount rates can be summarized by the assumed functional form.

the long-run marginal discount rate approaches $\rho = 1.42\%$.

5.2 General Equilibrium Asset Pricing

A number of general equilibrium models of asset pricing tend to produce term structure of discount rates for risky cash-flows that are either flat or upward sloping. We review this theoretical feature by focusing on three leading general-equilibirum models of asset pricing: the external habit formation model of Campbell and Cochrane (1999), the long-run risk model of Bansal and Yaron (2004), and the variable rare disaster model of Barro (2006) and Gabaix (2012). These models were not specifically set up to understand the term structure of risky assets; our intent is only to review their predictions for our data to set the base for future research.[28] In the next section we briefly discuss a number of promising modifications to the existing general equilibrium models that could help to accommodate our new stylized facts.

In the long-run risk model of Bansal and Yaron (2004) agents have a preference for early resolution of uncertainty and are concerned about shocks that persistently affect the growth rate of consumption. Therefore, agents dislike claims to very long-term cash flows that are exposed to these long-run risks. The model can match the expected return to housing if housing is sufficiently exposed to long-run risks. The model also implies that leaseholds with longer maturity are more exposed to long-run risks and command higher risk premia; thus contributing to generating an upward sloping term structure of discount rates for claims to rents.

In the external habit model of Campbell and Cochrane (1999) agents care about their surplus consumption relative to a habit level, which itself depends on the history of aggregate consumption. Negative shocks to consumption, with which rents are correlated, increase risk premia because they bring current consumption closer to the habit level. Long-term claims, due to their high duration, are particularly exposed to these discount-rate shocks and are therefore particularly risky. The model implies an upward sloping term structure of discount rates.

In the rare disasters model of Barro (2006) and Gabaix (2012) consumption growth is subject to rare but large negative shocks, the disasters. Agents dislike assets that are exposed to these disasters. While the presence of rare disasters increases risk premia, it does so uniformly across maturities because claims to cash flows at all horizons are equally exposed to the disaster risk. Therefore, discount rates will be the same at all horizons generating a constant term structure.

[28] Appendix A.4.2 discusses each of these models, their calibration, and their implications for our results in more detail.

5.2.1 Promising Avenues of Research

We now discuss some recent and interesting avenues of theoretical research that could potentially generate new classes of general-equilibrium asset pricing models that rationalize the findings of this paper.

A first family of models focuses on mean-reversion in cash flows and stochastic discount factors that mostly price near-term shocks. Lettau and Wachter (2007) propose a reduced-form model in which the only priced shock is the unexpected one period innovation in rents (dividends). In the model, unexpected rent growth today is negatively correlated with future rent growth. Therefore, long-term claims to future rents are safer than short-term claims because short-term claims do not benefit as much from the future increase in rent growth that follows a negative shock. The top right panel of Figure 6 shows that this model is able to match the magnitudes of the discounts at different horizons, since long-term claims in the model are safer and therefore command lower discount rates; the higher short-term discount rates, as high as 12% for one-year rents, allow us to increase the expected returns of freeholds (up to 4% in this calibration).[29] Notice that the model generates a flat term structure of risk-free discount rates consistent with the one observed for U.K. real gilts. In the spirit of partial reversion in the cash-flow process, Nakamura et al. (2013) extend the rare disaster model to allow for (an empirically estimated) increase in expected growth following a disaster. This pick-up in growth after a disaster makes long-run consumption safer than short-run consumption thus generating a downward sloping term-structure of discount rates for risky claims.

A second promising avenue is to expand on the reduced-form hyperbolic-exponential framework illustrated above. The models of Laibson (1997) and Luttmer and Mariotti (2003) consider the possibility that agents attach higher discounts to short-term cash flows than they do to long-term ones. In these models the variation in discount rates is driven by variation in the subjective discount factor, i.e. the rate of time preference. This approach has had widespread success in describing individual behavior in disaggregated environments, but has proven more difficult at the macroeconomic level due to problems of time inconsistency as well as the potentially countervailing equilibrium consequences

[29] See the original reference for model details. In calibrating the model, we tried to 1) match the observed leasehold discounts, while at the same time 2) retaining plausible estimates of short-term discount rates, and 3) obtaining a high expected return for the freehold. In particular, to obtain plausible short-term discount rates, we constrain the short-term (one-year) discount rates to be below the discount rates estimated for dividend strips by Binsbergen, Brandt and Koijen (2012), of 12%. The calibration of the model that gets closest to achieving all three objectives uses a growth rate of rents of 0.3% per year, a volatility of dividends of 0.04 per quarter and a persistence of dividend shocks ϕ_z of 0.865 per quarter. This calibration implies an expected return of housing 4%, relatively close to the target of 6.5%. Note that Lettau and Wachter (2007) exogenously set the level of the real yield to be 2%; this value is sufficiently close to the 1.4% observed in the U.K. data that we left it unchanged in our parametrization of their model.

that generate flat term structures of discount rates even in the presence of agents with hyperbolic time preference (Barro, 1999). A related term structure of discount rates can be obtained in an environment where agents have constant discount rates as long as there is uncertainty about the appropriate level of that discount rate. Weitzman (1998, 2001) points out that disagreement about the discount rate implies that long-term cash flows should be discounted at the lowest discount rate that is assumed to occur with positive probability. It remains an open question whether a micro-founded general-equilibrium time-consistent model that generates a discount function similar to the one postulated in Section 5.1 can be designed in future research. In ongoing work Eisenbach and Schmalz (2013) provide an intriguing avenue of research by making the risk-aversion coefficient, rather than the rate of time-preference, dependent on the horizon.

5.3 Environmental Policy

> *Any consideration of the costs of meeting climate objectives requires confronting one of the thorniest issues in all climate-change economics: how should we compare present and future costs and benefits? [...] A full appreciation of the economics of climate change cannot proceed without dealing with discounting.* **(Nordhaus, 2013)**

The economics literature on climate change, starting with the seminal paper of Nordhaus (1973), has long focussed on the central importance of discounting to evaluating the tradeoff between the immediate costs of climate change mitigation policy and its uncertain benefits that occur very far in the future.[30] The debate has mostly relied on theoretical arguments about the appropriate discount rate. For example, Stern (2007) argues for 0% discount rate on ethical grounds that require the present generation to not discount the welfare of future generations. Nordhaus (2007) points out that a 0% discount rate cannot be reconciled with economic theory because it would imply an enormous burden on the current generation by attaching infinite values to many investments that are routinely available in private markets at finite prices.

On the empirical side the debate tried to infer discount rates from the realized returns of traded assets such as private capital, equity, bonds, and real estate. These estimates of expected returns, however, reveal only the average returns on these assets. For example, our estimates in Table 8 suggest that the average real returns to residential housing are above 8%. However, the crucial estimates to evaluate climate-policy are the discount rates

[30]See also: Lind (1982); Cline (1992); Nordhaus (1992); Arrow et al. (1996); Weitzman (1998); Nordhaus (2001); Groom et al. (2005); Gollier (2006); Dasgupta (2007); Nordhaus (2007); Weitzman (2007); Gollier and Weitzman (2010); Gerlagh and Liski (2012); Goulder and Williams (2012); Pindyck (2013); Weitzman (2013).

for cash-flows very far into the future.[31] We found such discount rates to be much lower than those implied by average returns and of the order of 2.6% or less.

To derive implications of our results for climate change policy, we first turn to the question of the risk characteristics of investments in climate change abatement technology. There is an open debate over such characteristics with some researchers suggesting that they are risky investments, the payoff of which is positively correlated with future economic outcomes (Gollier, 2013) and other economists pointing out that these investments are a hedge against future disastrous states and therefore similar to insurance contracts (Weitzman, 2012). We summarize the arguments below.

The first argument points out that the cost of climate change depends positively on economic growth because they are a by-product of production. Therefore, carbon emissions will be high in future states of the world when consumption is also high, and low otherwise. This makes climate change a hedge and investments that aim to reduce climate change are risky. Along these lines Gollier (2013) simulates the DICE model of Nordhaus (2008) and Nordhaus and Boyer (2000) and finds a $\beta > 1$ for investments in climate change abatement technology. The second argument points out that there could be disastrous climatic outcomes that lead to low consumption via feedback loops. In this view climate change is similar to a rare disaster and, consequently, investments that aim to reduce climate change are very safe (in fact hedging) investments. Weitzman (2012) builds a theoretical model where climate change abatement investments have a tail-hedge property because they pay a positive amount in states of the world when consumption is extremely low.

With a high price of long-run risk, these two views imply very different optimal investments in climate change abatement technology: Weitzman (2012)'s model suggests a high willingness to invest, Gollier (2013)'s model a low willingness to invest. Recall that our estimates of long-run discount rates suggest that agents attach high present value to risk-free investments that pay far into the future and that they are relatively unconcerned with long-term risks. Both factors contribute to generate low long-run total discount rates for risky long-term assets. Barro (2013), however, points out that to understand the implications of discount rates for climate change investments it is paramount to distinguish between the risk-free component ($R^f_{t,t+T}$) and the risk-premium component ($RP_{t,t+T}$). Our results suggest that agents have a high willingness to invest in climate change abatement projects that reduce *for sure* the future cost of climate change because we find low long-run yields for risk-free cash flows. However, our results also suggest that agents have relatively less willingness to invest in climate change abatement projects that only reduce

[31] Of course in models with constant discount rates the average return provides all the necessary information. We have, however, shown in Section 4 that such models cannot be reconciled with the data.

the *risk* of adverse future climatic events because we find low long-run risk premia.[32]

We consider the role of discounting in three leading environmental models: the DICE model of Nordhaus and Boyer (2000) and Nordhaus (2008), the parameter uncertainty model of Gollier (2013), and the Gamma and tail-hedge discounting models of Weitzman (2001, 2012). It is beyond the scope of this paper to provide a full account of these models and we focus here only on the elements of discounting that are relevant for our purpose.

Nordhaus and Boyer (2000) and Nordhaus (2008) developed the key workhorse model of climate change: the dynamic integrated climate-economy (DICE) model. This model features a constant rate of discounting, often calibrated to be 4% (Nordhaus, 2013).[33] Our work suggests that an extension of the workhorse model should feature a declining discount rate parametrized using discount rates that directly relate to the long horizon.

Gollier (2013) evaluates climate change policy in a model that combines parametric uncertainty about the growth rate of the economy with uncertainty about the probability of rare disasters. The model, in its benchmark parametrization, produces a downward sloping term structure of risk-free discount rates, but an upward sloping term structure of risk premia. The second effect dominates for investments that are sufficiently risky, thus generating an upward sloping term structure of total discount rates for climate change investments in Gollier's parametrization.[34]

Our empirical estimates of discount rates are consistent with the decreasing term structure of discount rates suggested by Weitzman (1998, 2001). Weitzman (2001) generates a downward slope in an environment where a number of experts, who are assumed to have a constant discount rate, are polled regarding the appropriate level of the discount rate for environmental policy. Weitzman (2012) shows that if climate change abatement investments hedge tail risk by paying a positive amount in catastrophic states of the world when aggregate consumption is very close to zero, then the associated term structure of risk premia is downward sloping. Our empirical results provide a broader message of risk premia that decrease with the horizon even for risky assets. We find this message to be particularly important given the reasonable disagreement among economists over the

[32]Our estimated discount rates reflect *private* decisions and, arguably, represent an upper bound for the *social* discount rates that governments may wish to apply to climate change policies. It is often argued that climate change policy is affected by externalities that lead individuals to undervalue, compared to society as a whole, investments in climate change abatement.

[33]In setting this rate Nordhaus favors an "opportunity cost approach", i.e. he considers the returns to alternative investments of similar riskiness that the government could undertake instead of investments in climate change. The 4% is chosen to reflect the author's preferred estimate of the average return to capital (see also Piketty, 2014).

[34]Gollier (2013) derives a $\beta = 1.32$ for investments in climate change abatement and shows that for this investment the term structure of discount rates is upward sloping on average with a long-run discount rate of 4.6%.

riskiness, the β, of climate change abatement investments illustrated above.

5.4 Rational Bubbles

Our estimates of long-run discount rates can also be used to *directly* test for the presence of infinitely-lived rational bubbles. The existence of bubbles is one of the most fundamental, oldest, and most difficult questions in economics. In their recent survey of the literature on bubbles, Brunnermeier and Oehmke (2013) emphasize that "identifying bubbles in the data is a challenging task. The reason is that in order to identify a bubble, one needs to know an asset's fundamental value, which is usually difficult to measure." We show that this is not the case for our tests, which are *model independent*.

The classic infinitely-lived rational bubble models of Blanchard and Watson (1982) and Froot and Obstfeld (1991) feature a failure of the no-bubble condition, which is routinely imposed in most economic models. The no-bubble condition requires that the present value of a payment occurring in the limit as the horizon goes to infinity is zero:

$$\lim_{T\to\infty} E_t[\xi_{t,T} P_T] = 0,$$

where $\xi_{t,T}$ is a model-implied discount factor between date t and T and P_T the price of the asset at time T. Our data is uniquely suited to test this condition because we can estimate the present value of a claim to rents occurring at very long horizons, for example $T = 999$ years. More formally:

$$P_t - P_t^T \approx \lim_{T\to\infty} E_t[\xi_{t,T} P_T], \qquad \text{for large T.}$$

Intuitively, the difference in value between a freehold (P_t) and a 999-maturity leasehold (P_t^{999}) is the present value of the claim to rents starting 999 years from today and extending to the infinite future (i.e. the present value of a freehold 999 years from now, $E_t[\xi_{t,999}\, P_{999}]$). Therefore we can test whether the no-bubble condition holds, on average, by testing whether the discount of very long leases to freeholds is zero. We correspondingly formulate our null hypothesis of no-bubbles as: $Disc^T = 0$ for $T > 700$ years.[35] The estimates of extreme long-run discounts for Singapore and the UK are reported in Figures 1 and 3. In all cases the point estimates of the discounts are negligible and not statistically significant for T sufficiently large, 700 or more years. We conclude that there

[35] Our test differs from the predictability test for bubbles suggested by Cochrane (2011) because we test the existence of a bubble directly in the level of an asset price. Cochrane's test focuses on whether the bubble accounts for any variation in price-dividend (or price-rent) ratios over time and therefore cannot rule out the existence of a constant, and possibly sizable, bubble.

is no evidence in our data supporting the presence of infinitely-lived rational bubbles.[36] As an even more stringent test, Figure 7 show that there is no evidence of a bubble at any point in time between 2003 and 2013 in the UK (top panel) and between 1995 and 2013 in Singapore (bottom panel). It does so by showing that the price of freeholds P_t and those of leaseholds with more than 700 years of maturity left $P_t^{>700}$ are essentially identical, and certainly within the 1% confidence interval of each other, at all points in time.

This latter time-series test is of particular interest because it shows the absence of an infinitely-lived rational bubble even at the peak of the housing market in 2007 after years of strong house price growth, when many commentators were hinting at the presence of a large bubble. For example, Gali (2014) motivates his theoretical analysis of infinitely-lived rational bubbles by appealing to this consensus view: "the spectacular rise (and subsequent collapse) of housing prices experienced by several advanced economies over the past decade is generally viewed as a key factor underlying the global financial crisis of 2007-2009, as well as a clear illustration of the dangers associated with speculative bubbles that are allowed to go unchecked". In contrast to this consensus view, we find no evidence of this type of bubble.

The strength of directly testing the no-bubble condition is that all models that assume the absence of infinitely-lived rational bubbles have the same implication: that the fundamental present value of a payment occurring in infinite time ($\lim_{T\to\infty} E_t[\xi_{t,T} P_T]$) is equal to zero. We do not need to specify a model (a choice of $\xi_{t,T}$ and of a stochastic process for rents) in order to obtain a fundamental value to compare to the valuation in the data. All no-bubble models imply that such fundamental value is zero. Our direct testing methodology is made possible by the uniqueness of our data that allows us to identify the terminal no-bubble condition. Such tests have been elusive because we do not normally observe traded claims to payments that only occur extremely far into the future. Our direct tests contrast with a large previous literature (for example: Flood and Garber (1980); Evans (1991); Diba and Grossman (1988*b*,*a*); West (1987)) that had to either deal with the thorny problem of establishing fundamental values or find indirect ways to test for bubbles.[37]

We note, however, that our bubble tests should not be interpreted as providing evidence for the absence of *all types* of bubbles. We provide evidence against a specific type of bubble that is common in the theoretical literature: the infinitely-lived rational bubble. Our tests are uninformative with respect to the presence of finitely-lived bubbles of the

[36]While the literature has already put forward theoretical arguments for the fragility of the existence of infinitely-lived rational bubbles (for example Tirole, 1985), our tests provide direct empirical evidence for the absence of such bubbles.

[37]See Flood and Hodrick (1990) for a review of the deep econometric problems that had a chilling effect on the empirical literature attempting to test for the presence of bubbles.

kind described for example in Abreu and Brunnermeier (2003) and DeMarzo, Kaniel and Kremer (2008).

6 Further Robustness Checks

We have so far analyzed the discounts in light of simple models of asset pricing that abstract from a number of frictions. We find the abstraction very useful in order to focus on the most important economic insights, but we clearly do not ignore the fact that housing markets are not frictionless. We focus here on three possible frictions: financing frictions, taxation, and option value from extending the lease.

6.1 Financing Frictions

Financing frictions have the potential to affect the relative valuation of leaseholds and freeholds.[38] Leaseholds, in particular short dated ones, require lower upfront payments to take ownership of a property. If households have high future income that they cannot borrow against, these shorter leaseholds are more attractive than longer leaseholds or freeholds, in particular given the ability to extend leaseholds at the leaseholder's request. This credit constraint effect makes shorter leaseholds more desirable, *increasing* their valuation relative to a frictionless benchmark. Since this effect biases the empirical analysis against finding large leasehold price discounts, we do not assess its quantitative implications.

We focus instead on the possibility that short maturity leaseholds are harder to finance than long maturity ones. For example, U.K. mortgage lenders typically require 30 years unexpired lease term to remain at the end of the mortgage (Council of Mortgage Lenders, 2013). Mortgages in the U.K. generally have maturities between 10 and 30 years with the most common term length being 25 years. This means that leasehold purchases have to be financed with shorter duration mortgages once the lease length falls below 55 or 60 years. The loss in "collateral value" for these leaseholds could contribute to the large discounts we observe in the data, particularly for leases in the $50-70$ years range of maturity.

It is beyond the scope of this paper to provide a full general equilibrium model of housing in the presence of collateral and borrowing constraints. Instead we consider a simple deviation from the constant-discount-rate model in Section 4.1 to quanitfy the

[38] See Mian and Sufi (2009); Keys et al. (2012) for a discussion of the importance of financing frictions in housing markets. In Appendix A.1 we also discuss why ground rents and service charges cannot explain the observed discounts between leaseholds and freeholds. Many other frictions, such as long-run uncertainty about the enforcement property rights in countries such as Singapore should reduce the relative valuation of freeholds compared to leaseholds.

impact of a reduced form collateral constraint on leasehold discounts. We assume that for the last $\bar{T}$ years of lease maturity the property has lower collateral value modeled via an effective rent for the last $\bar{T}$ years that is a fraction $(1-\alpha)$ of the true rent.[39] The value of the lease and the implied leasehold discounts with respect to freeholds are given by:[40]

$$\begin{aligned} P_t^T &= \int_t^{t+T} e^{-\rho(s-t)} D_t e^{g(s-t)} (1-\alpha \mathbf{1}_{\{s>t+T-\bar{T}\}}) ds; \\ Disc_t^T &= e^{-(\rho-g)T} + \alpha\left(e^{-(\rho-g)(T-\bar{T})} - e^{-(\rho-g)T}\right) - \mathbf{1}_{\{T<\bar{T}\}}\, \alpha \left(e^{-(\rho-g)(T-\bar{T})} - 1\right). \end{aligned} \tag{7}$$

To asses the quantitative implications of this friction we set $\bar{T}=60$, we maintain the benchmark values of $r=6.5\%$ and $g=0.7\%$, and explore a range of values for α between 5% and 20%. A value of α of 20% implies that a 60-year leasehold is worth 20% less than it would have been in the absence of this collateral friction. Even at such high levels of the friction, the model cannot match the empirical leasehold price discounts at most horizons.

Most importantly even unrealistically high assumptions on the loss of collateral value for short duration leaseholds cannot help to explain the discounts for leases of long maturities (for example 150 or 250 years). Intuitively, a lease that has 200 years left today will only incur direct losses of its collateral value 140 years from now, when the lease will have 60 years left. Any losses that occur so far into the future have little impact on present values at conventional discount rates. To illustrate this effect, we calibrate the model choosing $\alpha=0.78$ so as to match by construction the price discount for the 80-100 year maturity bucket. Even under this calibration, there is little impact on the leasehold discounts at long maturities: 125-150 year maturity backer has a discount of 1.5% compared to the 8% estimated in the data.

6.2 Taxation and Options to Extend the Lease

Purchases of property in the U.K. are subject to stamp duty, a transaction tax. The tax applies equally to freehold or leasehold purchases. The tax schedule is progressive: for example, a purchase of a property with price in the 0-125,000 pound range is tax exempt, a purchase of a property with price in the 125,001-250,000 pound range is taxed at 1% of the *total* purchase price, and a purchase in the range of 250,001-500,000 is taxed at 3% of

[39]This loss corresponds to the per-period shadow value of liquidity (i.e., the per-period cost to the buyer of having to use own resources or a shorter duration mortgage). Alternatively, we can interpret α as the total loss in value once the leasehold reaches 60 years of remaining maturity due to the fact that new potential buyers will no longer have access to long-maturity mortgages and might need to make a larger downpayment.

[40]The formulas are derived and discussed in more detail in Appendix A.4.4.

the *total* purchase price.[41] This tax schedule potentially makes shorter term leases more attractive because for the same property a shorter term lease might avoid incurring the higher tax bracket due of its lower purchase price compared to a longer term lease. We note that this effect would only affect buyers of properties that are very close (marginal) to the boundaries of the tax bracket; since the brackets are relatively large the effect on the average discount is unlikely to big quantitatively meaningful. We also note that the effect would make our results conservative by biasing the estimated leasehold price discounts toward finding small discounts compared to the frictionless benchmark.

Further frictions that could affect our results are the rights of leaseholders to extend their leases. UK legislation and court practice have over time sought to rebalance the power away from freeholders, historically the landed nobility, in favor of leaseholders, mostly private individual homeowners. The legislative concern was that the freeholder could hold-up a leaseholder seeking a lease extension by asking an unreasonably high premium for the purchase of extra years on the lease or charging high administrative costs for issuing the new lease. Freeholders tend to be large landed estates or companies holding several properties, in many cases hundreds of properties, and are therefore not only relatively unaffected by the extension of each specific lease but also able to enjoy economies of scale in accessing legal and valuation services. On the contrary, leaseholders tend to be private individuals often owning their main residence under the leasehold. Both their private cost of changing (selling and re-buying) house and their cost to seek professional and legal representation are higher. This asymmetry could generate a hold-up problem; a concern frequent enough that practitioners in the UK coined the jargon terminology "delaforce effect" to denote it.[42] These concerns could potentially make leasehold contracts less attractive and therefore contribute to the empirical leasehold price discounts that we estimate in the data.

UK legislation and court practice, however, have systematically alleviated this concern in recent years. Legislation passed in 1993, well before the beginning of our sample, has granted virtually all leaseholders who have lived in a property for more than two years the right to seek a statutory lease extension by 90 years in return for paying a premium. Appendix A.1.4 describes the legislation and extension procedure in more detail; we focus here only on the key elements. In particular, under the law the leaseholder has the right to extend the lease by 90 years by negotiating a premium with the freeholder. If a reasonable agreement cannot be reached, then the leaseholder can refer the matter to tribunals that will enforce a court settlement and establish the payable premium. Badarinza

[41]The complete current tax schedule is reported in Appendix A.1.3.

[42]The term stems from the legal case Delaforce v. Evans, 1970, that brought to the court attention the asymmetry in negotiating costs and outside options between freeholders and leaseholders.

and Ramadorai (2014) recently pointed out that court enforced settlements have occurred at estimated discounts favorable to leaseholders compared to those estimated based on market values in this paper. While the court decisions are somewhat infrequent, subject to legal and advisory costs that can run in the "tens of thousands of pounds",[43] and subject to a number of legal restrictions on how to determine valuations, they alleviate the concern that our discounts could simply be due to the hold-up problem.[44]

7 Conclusions

We provide novel estimates of very long-run discount rates by exploring unique features of the U.K. and Singapore housing markets where properties trade as either freeholds (infinite maturity ownership) or leaseholds of various maturities. We find low long-run discount rates. Given estimates of the riskiness of housing, our results imply that both long-run risk-free rates and risk premia are low. Such implications pose an interesting challenge for future research in asset pricing as well as provide guidance to the debate on climate change policy.

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[43] For example, see the Westminster City Council publication: https://www.westminster.gov.uk/sites/default/files/uploads/workspace/assets/publications/Homing-in-on-the-issues-Perspec-1375182291.pdf.

[44] The possibility of favorable tribunal decisions, and potentially cheaper extensions outside court as an indirect effect, could also increase the ex-ante valuation of leaseholds by prospective buyers, if they were to anticipate lower future costs of extensions. To the extent that buyers take this institutional feature into account, this mechanism would generate a bias against finding large discounts for leaseholds relative to freeholds. There are several reasons why buyers may discount the ex-ante value of this potential advantage, reducing the bias against our findings: transaction costs related to the extension process are significant, bargaining times are long (often more than two years), there is uncertainty about the outcome (which may involve going to court twice), and there is general low awareness by buyers about the details of the extension process. See Appendix A.1.4 for more details.

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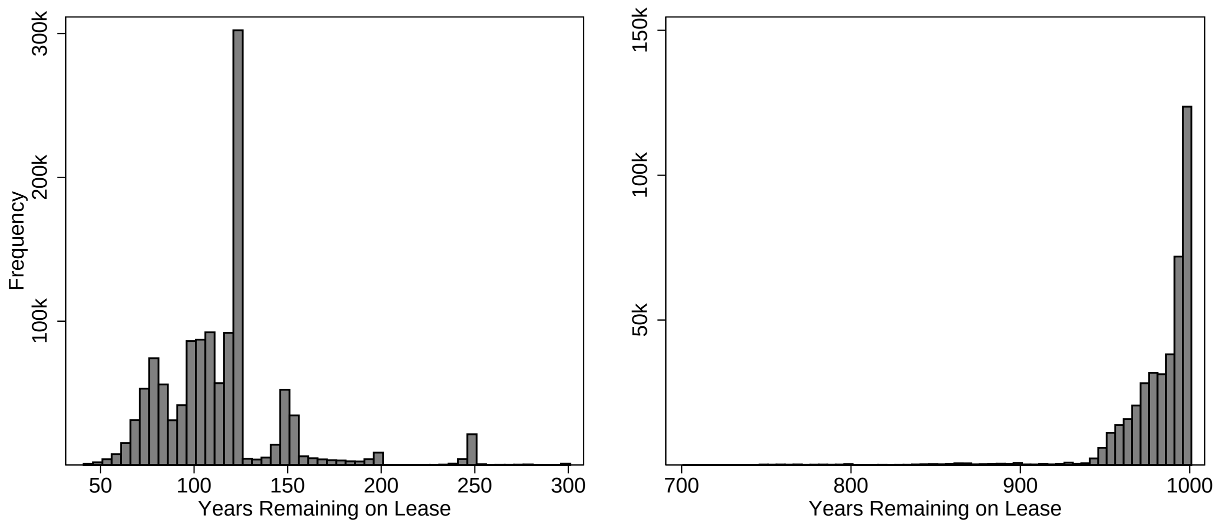
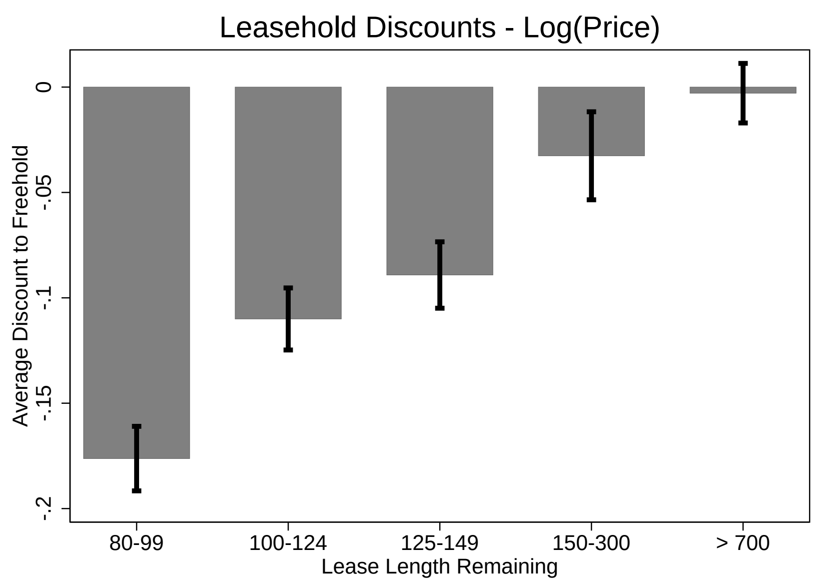
Figure 1: U.K. Flats - Sample and Price Discounts



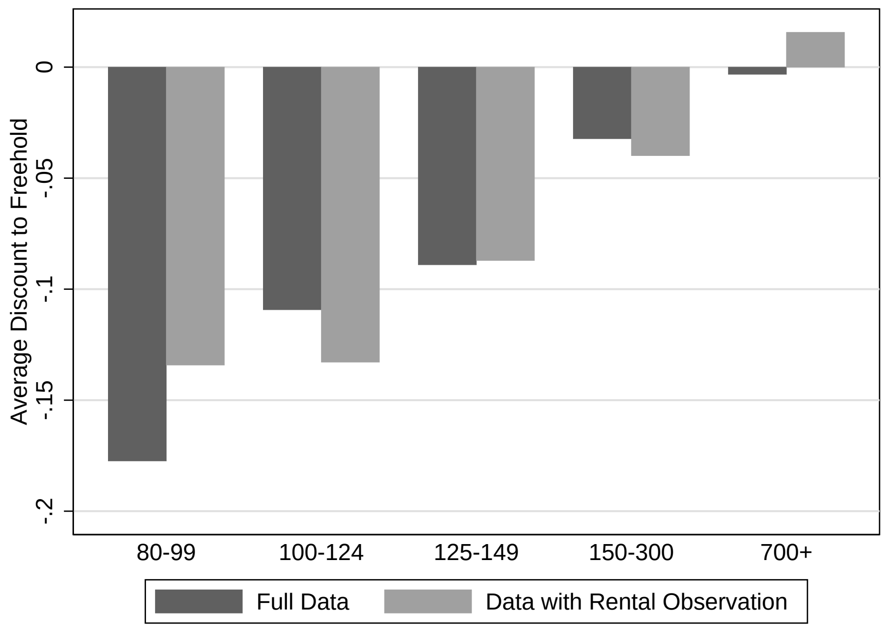
(a) Histogram of Remaining Lease Length



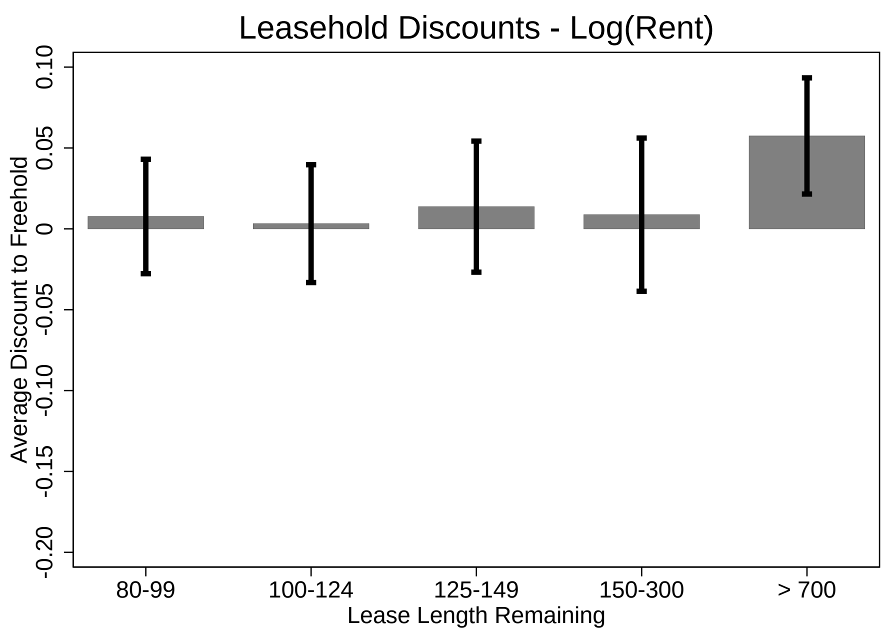
(b) Price Discount by Remaining Lease Length

Note: The top panel shows the distribution of years remaining on the lease at the point of sale for leasehold transactions for flats in our U.K. transaction sample. This bottom panel plots β_j coefficients from regression (1). The dependent variable is log price, for flats sold in England and Wales between 2004 and 2013. The price discounts of each of the groups of remaining lease length are relative to freehold properties, and correspond to column (1) in Table 2. We include 3-digit postcode by transaction month fixed effects. We also control for the size, number of bedrooms, bathrooms, property age, property condition, whether there is parking, and the type of heating. The bars indicate the 95% confidence interval of the estimate using standard errors double clustered by 3-digit postcode and by year.

Figure 2: Rental Data Analysis



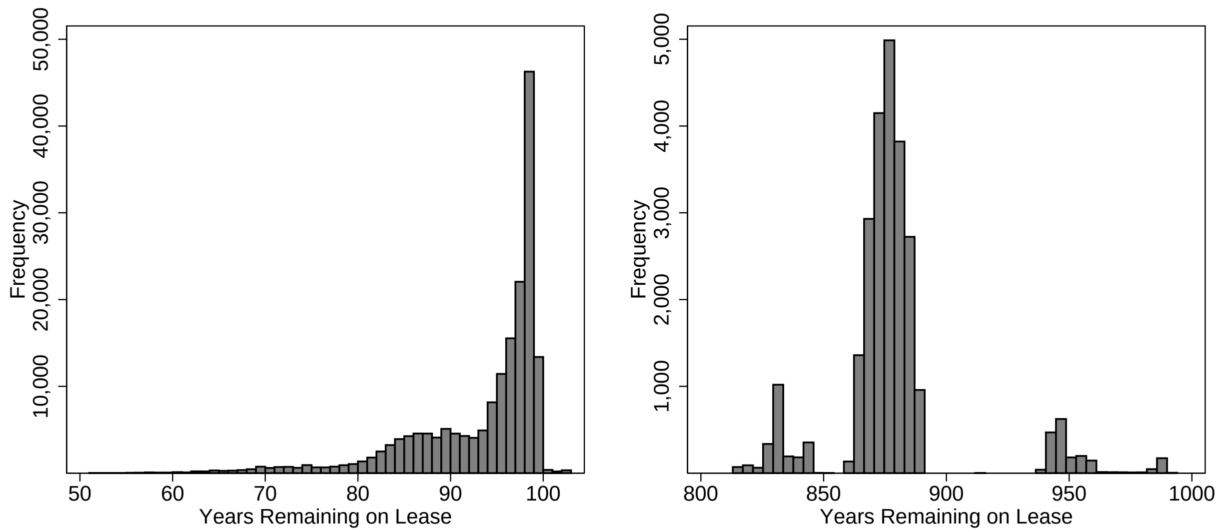
(a) Price Discount by Remaining Lease Length, Properties with Rental Data



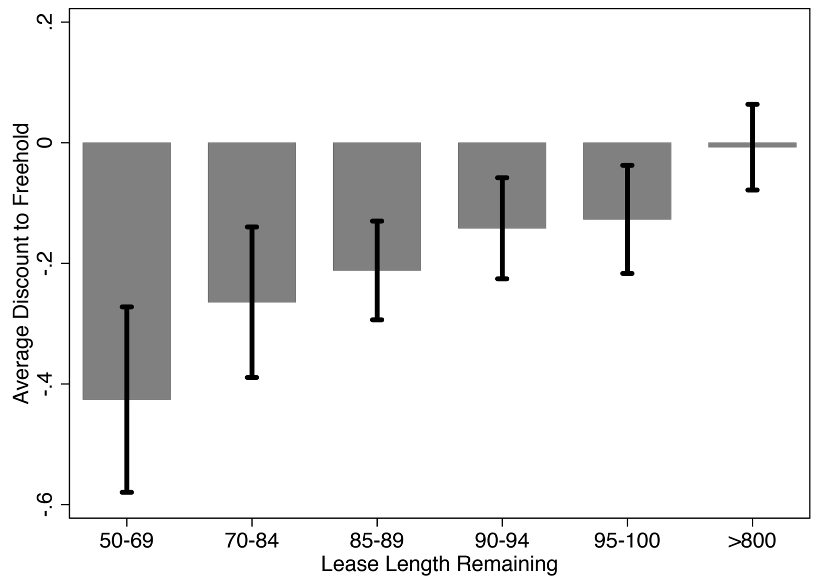
(b) Rental Discount by Remaining Lease Length

Note: The top panel of this figure shows β_j coefficients from regression (1) as in Column (1) of Table 2, allowing for a different coefficient for properties for which we observe rental data (second bar). The bottom panel shows β_j coefficients from regression (1), where the dependent variable are monthly rents. The sample is of flats listed in London in 2011 and 2012. The figure uses the same controls as in our baseline regression, Column (1) in Table 2. The bars indicate the 95% confidence interval of the estimate using standard errors double clustered by 3-digit postcode and by year.

Figure 3: Singapore Sample and Results



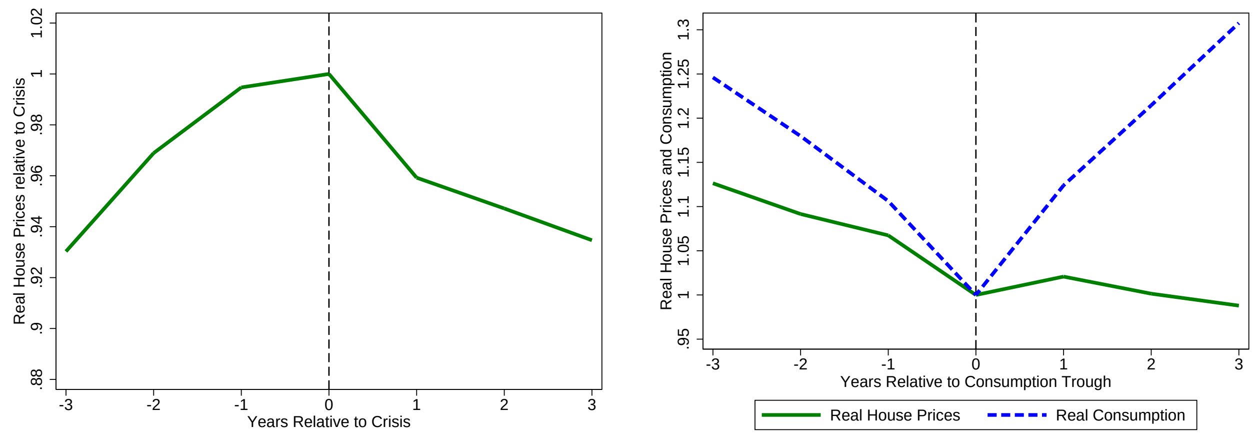
(a) Histogram of Remaining Lease Length



(b) Price Discount by Remaining Lease Length

Note: This top panel of this figure shows the distribution of years remaining on the lease at the point of sale for the leasehold transactions in our Singapore transaction sample. The bottom panel shows β_j coefficients from regression (3). Price discounts are relative to freeholds. The dependent variable is the log price paid for properties sold by private parties in Singapore between 1995 and 2013, corresponding to Column (2) in Table 7. We include fixed effects for the 5-digit postcode by property type (apartment, condominium, detached house, executive condominium, semi-detached house and terrace house) by title type (strata or land) by transaction month. We control for the age of the property (by including a dummy variable for every possible age in years), the size of the property (by including a dummy for each of 40 equally sized groups capturing property size) and the total number of units in the property. The bars indicate the 95% confidence interval of the estimate using standard errors double clustered by 5-digit postcode and by year.

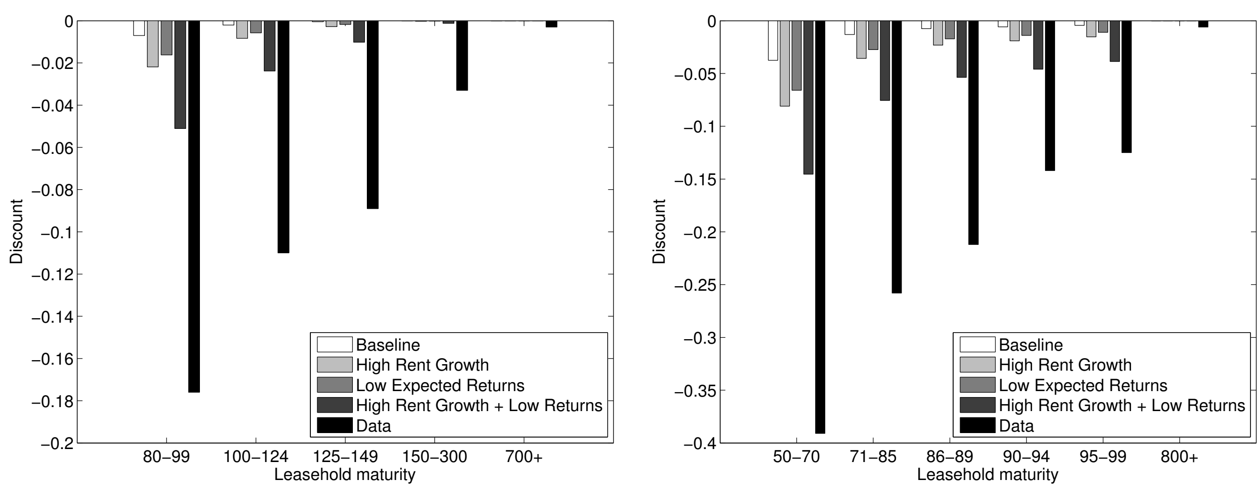
Figure 4: House Price Riskiness



(a) Financial Crises (b) Consumption Disasters

Note: The left panel shows average real house price movements relative to financial crises in Schularick and Taylor (2012), Bordo et al. (2001) and Reinhart and Rogoff (2009). The right panel shows average real house price movements and average real consumption relative to the trough of consumption disasters identified by Barro et al. (2008). House prices and consumption volumes during the reference year are normalized to 1. See Appendix A.3.3 for a description of the countries included and the data series and crises considered here.

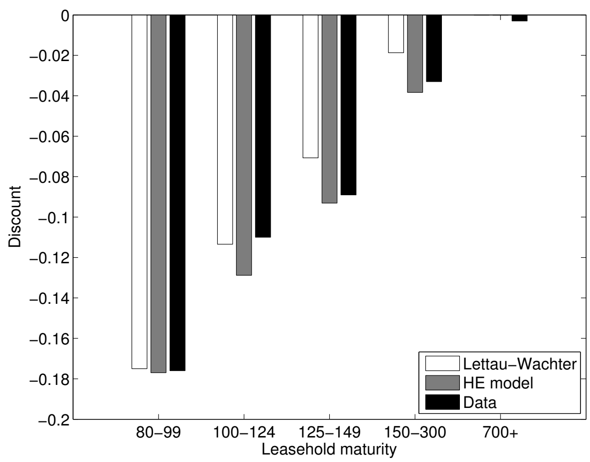
Figure 5: Constant Discount Gordon Growth Model: Model-Implied Discounts vs. Data



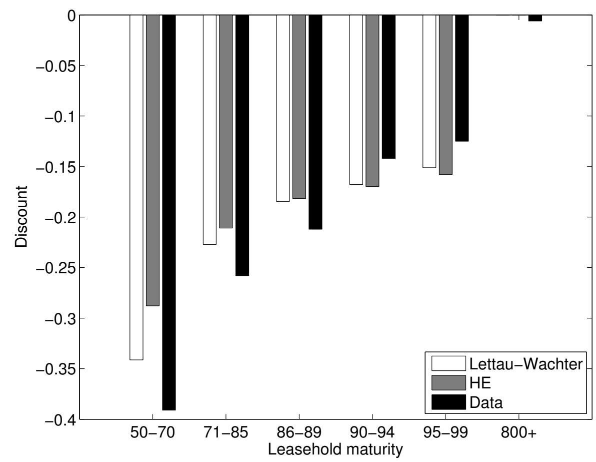
(a) U.K. (b) Singapore

Note: The figure shows the discounts for leaseholds observed in the U.K. (left panel) and Singapore (right panel) together with discounts predicted by a number of parameterizations of the constant discount model. The baseline calibration has $r = 6.5\%$ and $g = 0.7\%$. A "low expected return" calibration takes $r = 5.5\%$, while a "high rent growth" calibration takes $g = 2\%$.

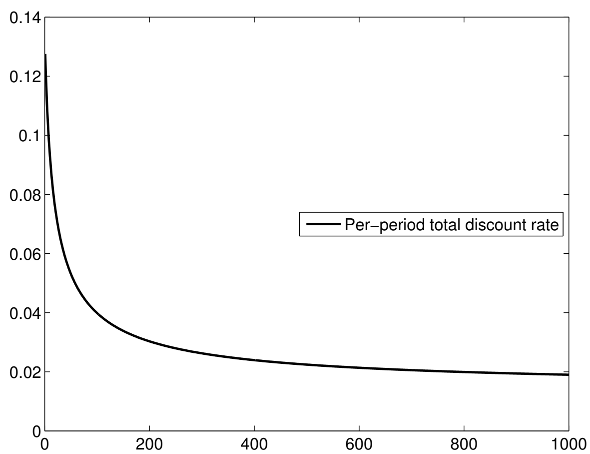
Figure 6: Hyperbolic-Exponential Discounting and Lettau and Wachter (2007)



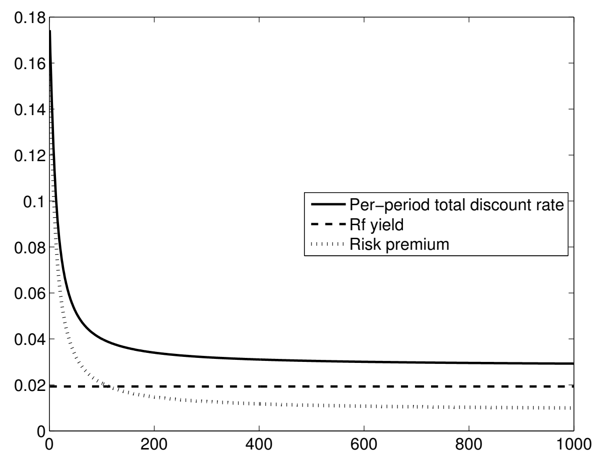
(a) U.K.



(b) Singapore



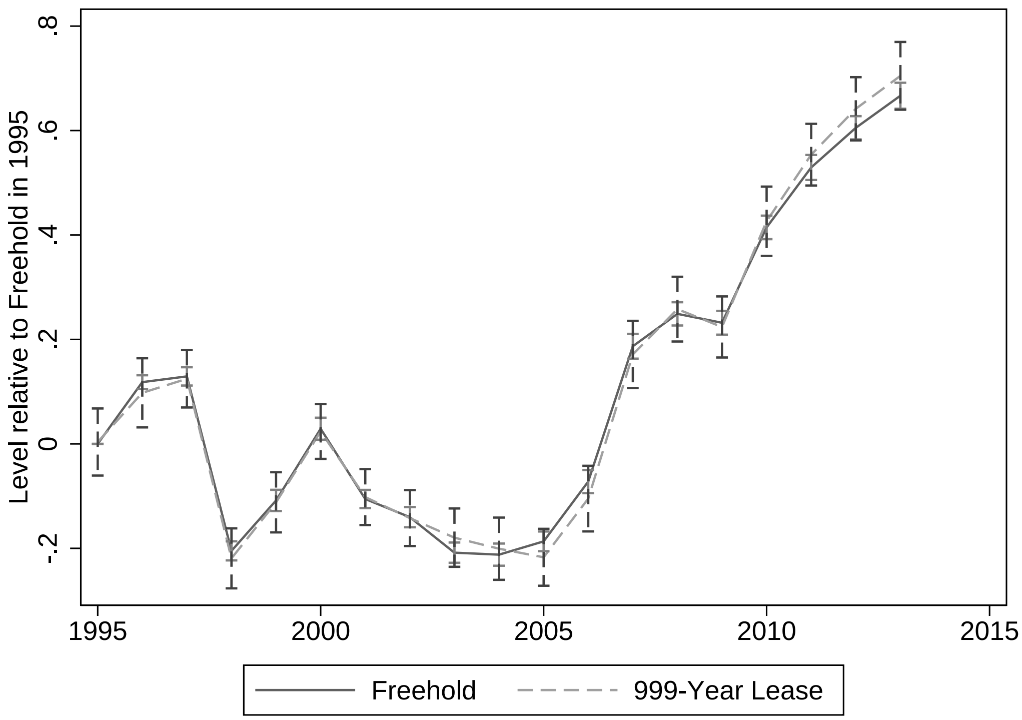
(c) Hyperbolic-Exponential



(d) Lettau and Wachter (2007) model

Note: The top row of the figure shows the discounts for leaseholds observed in U.K. (top left) and Singapore (top right) together with the discounts implied by a parameterizations of hyperbolic-exponential discounting reduced-form models and the Lettau and Wachter (2007) model in Section 5.1 using $r = 6.5\%$ and $g = 0.7\%$, $\kappa = 12\%$ and $\rho = 1.42\%$. The bottom row shows the total per-period discount rates for the hyperbolic-exponential discounting reduced-form model, and the total per period discount rates, risk-free yields, and risk premia for the Lettau and Wachter (2007) model.

Figure 7: Time Series of 999-Year Leases and Freeholds



Note: The figure shows the time series of the price level of 999-Year leaseholds and freeholds in Singapore between 1995 and 2013. Estimates are obtained from a regression of log(price/sqft) on 5-digit postcode by property-type by title-type fixed effects, the same control variables as Table 7 and a separate dummy for each year by lease type (Freehold, 99-Year Lease, 999-Year Lease). All price levels are relative to freeholds in 1995. The vertical bars indicate the 95% confidence interval of the estimates using standard errors clustered at the level of the fixed effect.

Table 1: Sample Overview U.K.

Flats	N	Share of Transactions by Contract: Freehold	80-99	100-124	125-149	150-300	700+
2004	183,599	0.03	0.19	0.37	0.08	0.05	0.28
2005	168,435	0.03	0.16	0.39	0.09	0.07	0.27
2006	212,734	0.03	0.14	0.39	0.10	0.08	0.27
2007	219,402	0.03	0.13	0.40	0.11	0.08	0.25
2008	116,048	0.03	0.12	0.41	0.11	0.10	0.24
2009	93,861	0.03	0.11	0.42	0.10	0.08	0.26
2010	99,663	0.02	0.13	0.41	0.09	0.08	0.27
2011	97,733	0.02	0.13	0.40	0.09	0.08	0.27
2012	98,464	0.02	0.14	0.39	0.09	0.08	0.29
2013	83,444	0.02	0.15	0.37	0.09	0.09	0.28
Total	1,373,383	0.03	0.14	0.39	0.09	0.08	0.27

Houses	N	Share of Transactions by Contract: Freehold	80-99	100-124	125-200	700+
2004	955,112	0.94	0.005	0.005	0.002	0.05
2005	803,983	0.94	0.005	0.005	0.002	0.05
2006	1,000,714	0.94	0.004	0.005	0.002	0.04
2007	942,575	0.94	0.004	0.006	0.002	0.05
2008	470,987	0.94	0.005	0.007	0.003	0.04
2009	480,827	0.95	0.004	0.005	0.002	0.04
2010	510,342	0.95	0.003	0.005	0.002	0.04
2011	513,179	0.95	0.004	0.004	0.002	0.04
2012	511,817	0.96	0.002	0.003	0.002	0.04
2013	438,598	0.96	0.002	0.003	0.002	0.03
Total	6,628,134	0.95	0.004	0.005	0.002	0.04

Note: This table shows the data sample for the U.K. analysis. The top panel is for flats, the bottom panel is for houses. For each year we show the number of transactions, as well as the share of transactions in each bucket by remaining lease length at the point of transaction.

Table 2: U.K.: Impact of Lease Type on Prices - Flats

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lease Length Remaining							
80-99 Years	-0.176***	-0.178***	-0.179***	-0.178***	-0.170***	-0.157***	-0.175***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.008)	(0.013)
100-124 Years	-0.110***	-0.109***	-0.106***	-0.110***	-0.105***	-0.111***	-0.073***
	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
125-149 Years	-0.089***	-0.088***	-0.086***	-0.090***	-0.083***	-0.086***	-0.060***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)
150-300 Years	-0.033***	-0.035***	-0.034***	-0.034***	-0.028***	-0.027***	-0.012
	(0.011)	(0.010)	(0.010)	(0.0011)	(0.011)	(0.010)	(0.012)
$>$ 700 Years	-0.003	-0.005	-0.005	-0.005	-0.005	-0.012	-0.004
	(0.007)	(0.006)	(0.006)	(0.007)	(0.007)	(0.008)	(0.007)
Fixed Effects	PC $\times$ M	PC $\times$ Q	PC $\times$ Y	PC $\times$ M	PC $\times$ M	PC $\times$ M	PC $\times$ M
Controls	✓	✓	✓	✓, $\times$ year	✓	✓	✓
Restrictions	·	·	·	·	Winsorize Price	Nonmiss. Hedonics	Exclude London
R-squared	0.729	0.721	0.712	0.731	0.738	0.776	0.616
N	1,373,383	1,373,383	1,373,383	1,373,383	1,373,383	953,660	1,028,031

Note: This table shows results from regression (1) estimated for flats. The dependent variable is log price, for flats sold in England and Wales between 2004 and 2013. To convert into percentage discounts for leasehold properties we compute $e^{\beta_j} - 1$. We include 3-digit postcode by transaction time fixed effects. In columns (2) and (3) the transaction time is the transaction quarter and year, respectively, in the other columns the transaction month. In column (4) we interact the controls with the transaction year. In column (5) we winsorize the price at the 1st and 99th percentile, in column (6) we only include properties for which characteristics are not missing, and in column (7) we exclude transactions in London. We also control for the size, number of bedrooms, bathrooms, property age, property condition, whether there is parking, and the type of heating. Standard errors are double clustered by 3-digit postcode and by year. Significance Levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

Table 3: Rents and Time on Market analysis

Dependent variable:		LOG(RENT)			LOG(TIME ON MARKET)	
	(1)	(2)	(3)	(4)	(5)	(6)
Lease Length Remaining						
80-99 Years	-0.021	0.001	0.008	0.059***	0.060***	0.047***
	(0.028)	(0.023)	(0.018)	(0.014)	(0.005)	(0.016)
100-124 Years	-0.024	-0.004	0.003	0.048***	0.048***	0.022*
	(0.028)	(0.024)	(0.019)	(0.011)	(0.005)	(0.013)
125-149 Years	-0.005	0.007	0.014	0.063***	0.060***	0.059***
	(0.030)	(0.026)	(0.021)	(0.013)	(0.009)	(0.020)
150-300 Years	-0.020	-0.001	0.009	0.080***	0.076***	0.071***
	(0.033)	(0.030)	(0.024)	(0.011)	(0.009)	(0.021)
$>$ 700 Years	0.037	0.051**	0.057***	0.028***	0.028***	0.017***
	(0.029)	(0.025)	(0.018)	(0.006)	(0.003)	(0.006)
Fixed Effects	PC and M	PC $\times$ M	PC $\times$ M	PC $\times$ M $\times$ Prop Type	PC $\times$ M $\times$ Prop Type	PC $\times$ M $\times$ Prop Type
Controls	✓	✓	✓	✓	✓, $\times$ year	✓
Restrictions	Nonmiss. Hedonics	Nonmiss. Hedonics	Nonmiss. Hed, Winsor.	·	·	Nonmiss. Hedonics
R-squared	0.674	0.746	0.766	0.070	0.092	0.073
N	29,020	29,020	29,020	2,409,181	2,409,181	1,290,825

Note: This table shows results from regression (1) where the dependent variable is the log of monthly rents in columns (1) to (3) and the log of time on market between listing and sale in days in columns (4) to (6). The sample for rent data is the universe of London flats for which rent and hedonics data is available on Rightmove.co.uk during 2011 and 2012. The sample for the time on market analysis is restricted to the sales of properties (both houses and flats) for which Rightmove.co.uk observes a for-sale listing. Controls are the same as in Table 2. Standard errors are double clustered by 3-digit postcode and by year. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

Table 4: Analysis with contract type fixed effects - Flats

	(1)	(2)	(3)	(4)	(5)	(6)
Lease Length Remaining						
80-99 Years	-0.123***	-0.124***	-0.123***	-0.126***	-0.118***	-0.120***
	(0.010)	(0.011)	(0.011)	(0.003)	(0.010)	(0.013)
100-124 Years	-0.096***	-0.098***	-0.100***	-0.095***	-0.105***	-0.070***
	(0.009)	(0.010)	(0.011)	(0.002)	(0.009)	(0.011)
125-149 Years	-0.083***	-0.086***	-0.088***	-0.083***	-0.089***	-0.069***
	(0.011)	(0.010)	(0.010)	(0.003)	(0.009)	(0.013)
150-300 Years	-0.055***	-0.054***	-0.053***	-0.057***	-0.051***	-0.049***
	(0.011)	(0.011)	(0.011)	(0.003)	(0.009)	(0.014)
$>$ 700 Years	0.013	0.013	0.013	0.012***	-0.006	0.010
	(0.019)	(0.020)	(0.023)	(0.003)	(0.012)	(0.010)
Contract Type - Initial Lease Length						
99 Years	-0.065***	-0.064***	-0.063***	-0.062***	-0.055***	-0.067***
	(0.011)	(0.011)	(0.012)	(0.002)	(0.010)	(0.010)
120 Years	-0.036***	-0.031**	-0.026**	-0.035***	-0.019*	-0.071***
	(0.012)	(0.012)	(0.012)	(0.003)	(0.011)	(0.015)
125 Years	-0.006	-0.008	-0.008	-0.008***	-0.003	-0.001
	(0.009)	(0.010)	(0.011)	(0.002)	(0.009)	(0.011)
150 Years	0.068***	0.070***	0.073***	0.066***	0.063***	0.070***
	(0.010)	(0.010)	(0.010)	(0.002)	(0.008)	(0.010)
155 Years	0.044***	0.047***	0.051***	0.044***	0.043***	0.051***
	(0.015)	(0.015)	(0.015)	(0.003)	(0.013)	(0.017)
199 Years	0.038*	0.035	0.032	0.039***	0.027	0.046*
	(0.021)	(0.022)	(0.024)	(0.003)	(0.016)	(0.024)
200 Years	0.039**	0.038**	0.038**	0.040***	0.036**	0.031*
	(0.016)	(0.017)	(0.019)	(0.004)	(0.014)	(0.016)
250 Years	0.035**	0.029*	0.028*	0.040***	0.042***	0.059***
	(0.015)	(0.016)	(0.017)	(0.003)	(0.015)	(0.015)
800 Years	0.111	0.070	0.067	0.103**	0.272**	0.137
	(0.167)	(0.168)	(0.170)	(0.044)	(0.113)	(0.166)
999 Years	-0.011	-0.011	-0.009	-0.012***	-0.005	-0.010
	(0.018)	(0.019)	(0.021)	(0.003)	(0.010)	(0.009)
Fixed Effects	PC $\times$ Y	PC $\times$ Q	PC $\times$ M	PC $\times$ Y	PC $\times$ Y	PC $\times$ Y
Controls	✓	✓	✓	✓, $\times$ year	✓	✓
Restrictions	.	.	.	.	Nonmiss. Hedonics	Exclude London
R-squared	0.715	0.724	0.732	0.717	0.766	0.586
N	1,373,383	1,373,383	1,373,383	1,373,383	953,660	1,028,031

Note: This table shows results from regression (1) estimated for flats, including fixed effects for the most common initial lease lengths of the contracts. The dependent variable is log price, for properties sold in England and Wales between 2004 and 2013. We include 3-digit postcode by transaction time fixed effects. In columns (2) and (3) the transaction time is the transaction quarter and month, respectively, in the other columns the transaction year. In column (4) we interact the controls with the transaction year. In column (5) we only include properties for which characteristics are not missing, and in column (6) we exclude transactions in London. We control for the size, number of bedrooms, bathrooms, property age, property condition, whether there is parking, and the type of heating. Standard errors are double clustered by 3-digit postcode and by year. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

Table 5: Characteristics of Buyers of Leaseholds and Freeholds: U.K.

	Sample		Leasehold Δ		
	Mean	St. Dev.	Unconditional	Conditional I	Conditional II
	(1)	(2)	(3)	(4)	(5)
Age Head of Household (years)	52.30	16.01	-2.68	-1.54	-1.30
				(0.21)	(0.20)
Weekly Income (£)	350.2	450.6	-48.07	-3.01	5.60
				(4.56)	(4.45)
Number of people in household	2.53	1.27	-0.48	-0.03	0.02
				(0.01)	(0.01)
Number of dependent children	0.55	0.94	-0.19	-0.01	0.02
				(0.01)	(0.01)
Head of Household Married	0.64	0.48	-0.21	-0.01	0.01
				(0.01)	(0.01)
First Time Buyer	0.40	0.48	0.11	-0.00	-0.01
				(0.01)	(0.01)
Currently Has Mortgage	0.59	0.49	0.03	0.02	0.02
				(0.01)	(0.01)
Very Satisfied with Neighborhood	0.47	0.50	-0.06	0.00	0.00
				(0.00)	0.00

Note: This table provides summary statistics on characteristics of owners of freeholds and leaseholds in the Survey of English Housing. The underlying contains information on 201,933 households in England surveyed between 1994 and 2008. The first two columns provide the sample means of the outcome variables. Column (3) provides the unconditional average difference between leasehold owners and freehold owners (e.g., on average, heads of household owning leasehold properties are 2.7 years younger than heads of households owning freehold properties). Columns (4) and (5) show the β coefficient of the following regression: $Outcome_i = \alpha + \beta Leasehold_i + \xi X_i + \phi_{PropertyType \times Region} + \varepsilon_i$. Column (4) does not include any additional controls in X_i, column (5) includes dummy variables for property age, the number of rooms and the floor on which the property is on (the control variables that overlap with the transaction dataset). In other words, these columns show the difference between freehold and leasehold owning households, conditional on living on the same property type (flat, semi-detached house, etc.) and living in the same local authority. Standard errors are double clustered by local authority code and by year.

Table 6: Data Sample - Singapore

		Share of Transactions by Contract						
	N	Freehold	50-70	71-85	86-90	91-95	96-100	800+
1995	12,412	0.575	0.001	0.034	0.029	0.004	0.270	0.087
1996	18,434	0.492	0.001	0.024	0.020	0.025	0.298	0.140
1997	12,534	0.402	0.001	0.045	0.003	0.023	0.453	0.073
1998	13,095	0.311	0.001	0.029	0.002	0.029	0.576	0.052
1999	23,500	0.503	0.002	0.044	0.002	0.064	0.304	0.082
2000	12,615	0.490	0.007	0.049	0.004	0.092	0.273	0.084
2001	11,577	0.392	0.005	0.036	0.015	0.107	0.406	0.040
2002	17,618	0.421	0.003	0.033	0.013	0.133	0.337	0.060
2003	9,807	0.441	0.006	0.055	0.035	0.140	0.262	0.061
2004	11,231	0.522	0.006	0.049	0.050	0.123	0.192	0.058
2005	16,771	0.575	0.014	0.039	0.057	0.111	0.134	0.070
2006	24,261	0.587	0.008	0.038	0.074	0.101	0.132	0.061
2007	39,203	0.521	0.013	0.040	0.126	0.083	0.138	0.079
2008	13,919	0.475	0.015	0.056	0.159	0.084	0.138	0.073
2009	32,967	0.490	0.011	0.056	0.106	0.064	0.194	0.078
2010	34,481	0.466	0.011	0.083	0.097	0.051	0.225	0.066
2011	25,236	0.378	0.009	0.083	0.070	0.040	0.370	0.049
2012	36,652	0.329	0.016	0.085	0.039	0.040	0.444	0.047
2013	15,215	0.267	0.014	0.067	0.026	0.049	0.535	0.042
Total	381,528	0.457	0.009	0.053	0.059	0.068	0.285	0.069

Note: This table shows the data sample for the Singapore analysis. For each year we show the number of transactions, as well as the share of transactions in each bucket by remaining lease length at the point of transaction.

Table 7: Impact of Lease Type on Log(Price) - Singapore

	Relative to Freehold					
	(1)	(2)	(3)	(4)	(5)	(6)
Lease Length Remaining						
50-70 Years	-0.409***	-0.426***	-0.464***	-0.487***	-0.424***	NA
	(0.067)	(0.078)	(0.030)	(0.089)	(0.074)	
71-85 Years	-0.275***	-0.264***	-0.469***	-0.273***	-0.262***	-0.328**
	(0.058)	(0.064)	(0.050)	(0.077)	(0.060)	(0.134)
86-90 Years	-0.215***	-0.212***	-0.111**	-0.216***	-0.210***	NA
	(0.038)	(0.042)	(0.048)	(0.048)	(0.039)	
91-95 Years	-0.148***	-0.142***	-0.169***	-0.146***	-0.142***	-0.179
	(0.038)	(0.043)	(0.049)	(0.048)	(0.040)	(0.529)
96-100 Years	-0.125***	-0.127***	-0.127**	-0.132***	-0.129***	-0.213
	(0.040)	(0.046)	(0.059)	(0.049)	(0.043)	(0.631)
> 800 Years	-0.010	-0.007	0.019	-0.002	-0.008	0.006
	(0.032)	(0.036)	(0.052)	(0.041)	(0.035)	(0.126)
Fixed Effects	PC × Q × Prop Type × Title Type	PC × M × Prop Type ×Title Type	PC × M × Prop Type × Title Type	PC × M × × Prop Type × Title Type	PC × M × Prop Type	PC × M × Prop Type
Controls	✓	✓	✓	✓	✓	✓
Restrictions	·	·	New Only	Private Buyer	Strata Only	No Strata
R-squared	0.977	0.979	0.981	0.978	0.977	0.985
N	378,768	378,768	223,810	220,044	333,684	45,084

Note: This table shows results from regression (3). To convert into percentage discounts for leasehold properties relatives to freeholds, construct $e^{\beta_j} - 1$. The dependent variable is the price paid for properties sold by private parties in Singapore between 1995 and 2013. We include fixed effect at the 5-digit postcode by property type (apartment, condominium, detached house, executive condominium, semi-detached house and terrace house) by title type (Strata or Land) by transaction date. In column (1), the transaction date interaction is for the transaction quarter, in columns (2) - (6) the transaction month. We control for the age of the property (by including a dummy variable for every possible age in years), the size of the property (by including a dummy for each of 40 equally sized groups capturing property size), and the total number of units in the property. In column (3) we only focus on properties that were bought by a private individual (and not the HDB); in column (4) we only focus on properties that were built within the last 3 years of our transaction date. In columns (5) and (6) we conduct the analysis for Strata and non-Strata titles separately. Standard errors are double clustered by 5-digit postcode and by year. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

Table 8: Expected Returns and Rental Growth

	United States		Singapore		United Kingdom	
	Balance Sheet	Price/Rent	Balance Sheet	Price/Rent	Balance Sheet	Price/Rent
Gross Return	10.3%	10.7%	10.4%	10.3%	12.5%	10.9%
Rental Yield	8.3%	9.8%	6.1%	6.0%	9.7%	6.9%
Capital Gain	2.0%	0.8%	4.3%	4.3%	2.8%	4%
Depreciation	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Taxes	0.67%	0.67%	0.5%	0.5%	0%	0%
Net Return	**8.1%**	**8.5%**	**8.4%**	**8.3%**	**11%**	**9.4%**
Sample	1953-2012	1988-2012	1985-2012	1990-2012	1989-2012	1996-2012
Real Rent Growth		0.1%		0.2%		0.7%
Sample		1988-2012		1990-2012		1996-2012

Note: This table shows our estimates for net real returns to housing and real rent growth in the U.S., the U.K. and in Singapore. See appendix A.3 for details.

Table 9: Time Series Properties of Real House Price Growth

	Period	Real HP Growth		Real Cons. Growth		
		Mean	Std. Dev.	Mean	Std. Dev.	Correlation
Australia	1901 - 2009	2.50%	12.1%	1.51%	5.00%	0.102
Belgium	1975 - 2009	2.92%	6.00%	1.56%	1.49%	0.438
Canada	1975 - 2009	2.38%	7.69%	1.64%	1.71%	0.433
Denmark	1975 - 2009	2.00%	9.24%	1.03%	2.68%	0.538
Finland	1975 - 2009	2.17%	8.70%	2.09%	2.75%	0.710
France	1840 - 2009	2.06%	11.8%	1.53%	6.32%	-0.054
Germany	1975 - 2009	-0.005%	2.33%	1.71%	1.56%	0.494
Japan	1975 - 2009	0.00%	4.45%	2.00%	1.59%	0.502
Italy	1975 - 2009	1.28%	8.10%	1.69%	2.12%	0.165
Netherlands	1807 - 2009	2.78%	21.6%	1.46%	7.57%	0.090
New Zealand	1975 - 2009	2.46%	8.01%	0.90%	2.34%	0.578
Norway	1830 - 2009	1.82%	11.6%	1.78%	3.83%	0.243
Singapore	1975 - 2009	7.18%	19.5%	3.37%	2.98%	0.348
Spain	1975 - 2009	3.15%	8.07%	1.54%	2.57%	0.593
South Africa	1975 - 2009	1.13%	10.1%	0.90%	2.98%	0.707
South Korea	1975 - 2009	0.60%	7.93%	4.58%	4.43%	0.370
Sweden	1952 - 2009	1.55%	6.04%	1.66%	1.98%	0.537
Switzerland	1937 - 2009	0.04%	7.17%	1.55%	3.85%	0.187
U.K.	1952 - 2009	2.89%	9.55%	2.22%	2.12%	0.700
U.S	1890 - 2009	0.04%	7.36%	1.80%	3.41%	0.148

Note: The table shows time series properties of annual growth rates of real house prices (as described in Appendix A.3.3) and real consumption, as collected by Barro et al. (2008). Column (1) shows the sampled considered. Columns (2) and (3) show the mean and standard deviation of real house price growth. Columns (4) and (5) the mean and standard deviation of real consumption growth. Column (6) shows the correlation of real house price growth and real consumption growth.

Appendix to "Very Long-Run Discount Rates"

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Not for publication

A.1 Institutional Appendix - United Kingdom

A.1.1 Historical Background

The history of leasehold property ownership in England has its roots in feudalism, a system of land use and ownership that was common in Europe between the tenth and thirteenth centuries, and introduced in England following the Norman Conquest. Land was owned and controlled by a military or political sovereign ruler, who gave portions of land that she owned to a number of lords as "tenants-in-chief," or "tenants-in-capite." The lord, in turn, could allow another person, a vassal, to use smaller portions of the land for a fixed period of time in return for pledging allegiance and military or other service to the lord. See Burn, Cartwright and Cheshire (2011) for a detailed review of the history of real property law.

McMichael (1921) describes the historical debate regarding the origins of common lease length terms of 99, 125 and 999 years: *Matthew Bacon, author of "A Treatise on Leases and Terms for Years" published in London, England, in 1798, explains in various parts of his book that the ninety-nine year period represents three lives, but Bacon does not indicate why such a term was selected as the length of time a lease was to prevail. It is supposed by some that there was an English common law which prevented a lessor from granting a lease for 100 years and that it was therefore made for a somewhat briefer period, but no real evidence has ever been found to substantiate this theory.* 1000-year leases were also common, with Jack Cade in Shakespeare's *Henry IV, Part II* exclaiming that "Now I am so hungry, that if I might have a lease of my life for a thousand years, I could stay no longer." McMichael (1921) also discusses theories of moving from 1000 year to 999 year leases: *Lord Coke, who lived in the reign of Queen Elizabeth, in his writings on the subject of leases suggested that a lease for 1,000 years might on its face suggest fraud and it is thought that to avoid such a contingency the lessors of those early days set upon 999 years as the extreme limit for the life of a lease. Such leases, in any event, were made at that time.*

During the 1920s various legislation was introduced to control rents and restrict the right of landlords to evict tenants. Many landlords, facing dwindling profits, started to sell long leases (typically 99 or 125 years) of their properties as a means of increasing revenue without losing ownership of their land. This marked the beginning of the modern leasehold system. As the construction of flats increased following World War II, leasehold ownership increased significantly. During that period, leasehold contracts were the only means available to subdivide and sell properties in a multi-occupancy building. This is because freehold ownership could not yet be applied to flats, as the relevant freehold property law required a separate land boundary to be visible on a map.[45]

A.1.2 Leasehold Registration

The registration of leasehold and freehold interest has been governed mainly by the 1925 Land Registration Act until a major reform in 2002 (with the 2002 Land Registration Act), which became effective in October 2003. The two Acts regulate the registration procedures of interests in real estate, both freeholds and leaseholds. In both cases, the law identifies cases in which registration of freehold and leasehold contracts is voluntary or mandatory, and disposes the limits and procedure to follow to register an interest. The main objective of the 2002 reform was to further encourage voluntary registration of contracts, and extended the cases of mandatory registration.

In particular, under the current law, registration of a contract is mandatory when a leasehold of 7 years or longer is granted or transferred, or a freehold is transferred. When no transfer occurs (or other event that triggers registration according to the law), registration is not mandatory, though encouraged by the law. This could for example be the case for lease extensions. Finally, the law establishes that failure to register an interest will make the interest lose the so-called overriding status: the owner of the interest may be vulnerable to successive transfer of the title that are registered.[46]

A.1.3 Tax Treatment of Leaseholds and Freeholds

Her Majesty Revenue and Customs (HMRC), the tax authority for England and Wales, gives equal treatment to the price paid for any term of leasehold or for a freehold when levying Stamp Duty Land Tax (SDLT) on residential property transactions. Transactions below £125,000 are exempt from stamp duty, with rates rising progressively thereafter, to 5% for houses above £1 million and 7% for houses above £2 million.[47] The tax rate

[45] See http://www.leaseextension-uk.info/leasehold-history.html for more details.

[46] For reference, see http://www.landregistry.gov.uk/professional/guides/practice-guide-15 and http://www.landregistry.gov.uk/professional/guides/practice-guide-25.

[47] See complete current tax schedule at: https://www.gov.uk/stamp-duty-land-tax-rates.

bands do not reflect marginal but total tax rates - a move into a higher tax band means that the higher rate is applied to the entire purchase. This would increase the value of the (cheaper) leasehold relative to freeholds, since they might end up in a lower tax band. Stump Duty is also levied on the premium payable under lease extensions. HMRC does not levy property taxes on actual ownership, it only taxes transactions (changes in ownership).

A.1.4 Leasehold Extensions

Over time, a number of laws have regulated the rights of leaseholders to extend their lease terms. There are three key Acts of Parliament that regulate this process. The 1967 Leasehold Reform Act enabled tenants of houses (not flats) held on long leases to acquire either the freehold (a process called "enfranchisement") or an extended lease term. The 1993 Leasehold Reform, Housing and Urban Development Act conferred rights to collective enfranchisement and lease extension on groups of flat owners in the same building who have been in occupation for a number of years. The Commonhold and Leasehold Reform Act of 2002 extended the right to lease extensions to individuals who have owned (but not necessarily occupied) flats for at least two years. In brief, these Acts confer the statutory right to 90 year lease extension to most leaseholders.

The Acts also codify the bargaining process for a lease extension in the following way. First, the leaseholder files a proposal for extension, with an offered premium for the extra years to be acquired on the lease. The freeholder agrees, or proposes a counteroffer, and the two parties then bargain on the final price of the extension. It is common for both parties to solicit both legal representation and the advice of professional valuers. This process can be expensive and time consuming with the administrative costs of extensions often costing £4,000-£5,000 and the proceedings taking over two years to complete.[48] The leaseholder is liable not only for his own costs but also for the legal, administrative, and valuation costs of the freeholder. In fact, the Acts established that the freeholder is to be compensated for "reasonable" costs incurred in connection with the lease extension; these costs are *in addition* to the premium payable for granting extra years on the lease.

If the two parties cannot agree on a price, the leaseholder can refer the matter to the Leasehold Valuation Tribunal (LVT) or, since July 2013, to the newly created First-Tier Tribunal (Property Chamber). Such tribunals are part of Her Majesty's Courts and Tribunals Service. Each tribunal usually consists of three members: a lawyer, who is often the chair-

[48] For an example of estimated costs see http://www.telegraph.co.uk/finance/personalfinance/9060279/Home-owners-urged-to-extend-leaseholds.html.

man, a valuer and a lay person. There were five regionally based LVT offices (London, Northern, Midland, Eastern and Southern). There is no administrative fee payable to the U.K. government for LVT applications to determine the terms or price in respect of enfranchisement or applications to determine the terms or price in respect of lease extensions. However, recurring to the LVT is generally a very last resort for leaseholders because of the mounting costs related to legal advice and representation, valuers' fees, and the uncertain and lengthy process involved in court decisions. Individual costs may vary, but are generally estimated to run in the "tens of thousands" of pounds.[49] Any order made by the LVT may be enforced, with the permission of the county court, in the same way as a county court order. A final layer of protection is granted via the appeal process: LVT or First-Tier Tribunal decisions can be appealed by either the freeholder and the leaseholder. The appeal is then judged by the Upper Tribunal (Lands Chamber).[50] The fee for lodging an appeal is £250. Further legal and valuation advice costs are incurred for the appeal and the court judgement can allow freeholders to recover these costs via increases in their service charge to leaseholders.

The legislation provides a number of restrictions on how the properties and lease contracts are to be evaluated by the tribunal in assessing the payable premium in case of lease extension or the enfranchisement cost in case of outright purchase of the freehold. The tribunal is instructed to consider the amount that the property "might be expected to realize if sold on the open market by a willing seller to a willing buyer," a reference to market values, but also to disregard a number of features that would actually affect market values. For example, the valuation is not supposed to include improvements made by the leaseholders and ignore the value of the option to extend the lease under the current (shorter) lease. For leaseholds below 80 years of term remaining the tribunal is also required to determine "marriage value". This is defined as the increase in value for the leasehold interest due to the longer length of the lease minus the decrease in value to the freehold interest for the same extension.[51] For leaseholds below 80 years this estimated marriage value is to be split equally between freeholder and leaseholder, while for properties above 80 years it accrues entirely to the leaseholder. In principle, this makes lease extensions below 80 years more expensive for leaseholders. In determining the valuations

[49] For example, see the Westminster City Council publication: https://www.westminster.gov.uk/sites/default/files/uploads/workspace/assets/publications/Homing-in-on-the-issues-Perspec-1375182291.pdf.

[50] Permission to appeal must first be requested from the First-Tier Tribunal, if this Tribunal does not grant permission to appeal, the permission can then be sought directly from the Upper Tribunal (Lands Chamber). See http://www.justice.gov.uk/tribunals/lands for more information.

[51] In some cases this value is also corrected for changes to ground rent. Under statutory lease extensions the new ground rent is set to the symbolic "peppercorn".

the tribunal relies both on the input of the leaseholder and the freeholder, but is actually not required to rule within that range.

The only market value actually observable from lease extension is the value of the premium, not the actual relative value of the extension compared to an identical freehold or long leasehold. While such reference points, which are sometimes called "relativity curves," are often discussed in the early stages of a lease extension are then dropped from further proceedings because the parties are only interested in determining the premium payable. Valuers and the tribunal often refer to comparable properties to determine market values, but an inspection of the decisions most often reveals that the process is based on relatively few comparables as well as subjective adjustments for market trends over time and different hedonic characteristics of the property.

As highlighted in Section 6 of the main draft, one possible concern is the asymmetry in power between freeholders and leaseholders when it comes to negotiating lease extensions. The asymmetry occurs because freeholders, most often large estates or companies, generally hold a large number of properties, while leaseholders are generally individual homeowners. The professional and deep-pocketed nature of freeholders as well as the large private moving costs to leaseholders if a reasonable extension of the lease cannot be achieved have historically created the danger of a hold-up problem that might have damaged leasehold interests. The subsequent legislation described above and the court process have actively tried to protect leaseholders by granting them both the right to a lease extension as well as court protection if such extension cannot be achieved in bilateral negotiations with the freeholder.

In ongoing work, Badarinza and Ramadorai (2014) have analyzed about 400 court decisions to grant lease extensions. They find the courts to have awarded extensions at premia more favorable to the leaseholders than the market valuations estimated in this paper. While the court valuations are subject to a number of arbitrary criteria such as leaseholders and freeholders guesswork of what the property might be worth in a market transaction that is not actually observed, such results alleviate the concern that our estimated discounts are purely due to the hold-up problem. In fact, if the courts decide on average on a basis more favorable to leaseholders, this should provide leaseholders with a more credible remedy in the bilateral negotiations with freeholders.

Of course, the threat of referring the matter to the court to take advantage of seemingly low premia in court settlements has to be balanced with the substantial costs of such an option. An hypothetical new homebuyer that wanted to take advantage of the legislation would have to buy the property, live in it for two years, and then hire a valuer and a solicitor to file for a lease extension; if a favorable extension cannot be agreed with the freeholder, the leaseholder has to file a complaint with the tribunal, and, even after the tribunal ruling, face the risk of an appeal to the Upper Tribunal from the freeholder. The potential length of this process runs into several years, the cost associated quickly rise to tens of thousands of pounds, and the outcome would still remain uncertain. These prospects are probably daunting for most leaseholders but should still contribute to lessening the hold-up problem.

We also find evidence that a large number of leaseholders do not take advantage of the possibility of cheaper lease extensions compared to market values. For example, we find that a large number of extensions (both in terms of market extensions described in Appendix Figure A.1 as well as in the cases before the LVT) occur when the lease has less than 80 years remaining; this suggests that leaseholders do not seem to take advantage of the opportunity granted by the law to avoid paying the “marriage value" if the lease is extended before it reaches the 80 year mark. The law, in fact, induces a discontinuity in the tribunal valuation of an extension with a 79 year lease paying more than an 80 year lease. It is possible that transactions costs, emotional costs of dealing with the negotiations, or simply inattention are connected with this phenomenon.

A.1.5 Ground Rents, Management Fees and Leasehold Covenants

There are three other important institutional features that might reduce the value of leaseholds relative to freeholds: ground rents, service charges and leasehold covenants. Below we describe the relevant institutional details. Neither is important enough to explain a significant part of the estimated difference. In addition, since ground rents, management fees and covenants are present for leaseholds of all maturities, the fact that 700+ year leaseholds trade at the same price as otherwise identical freeholds, and the fact that the discounts remain when estimated within leasehold properties, shows that they cannot contribute significantly to leasehold discounts relative to freeholds.

Ground Rents: A leaseholder sometimes has to pay annual ground rent to the freeholder. The original rationale for the ground rent was that the purchase price of the lease only covered the temporary ownership of the structure. The land still belongs to the freeholder who has the right to request that the lessee makes regular payments for the use of the land, the ground rent.

Ground rents are customized on a property by property basis and no centralized database exists. This makes it hard to control for them in the regression analysis. However, the amounts involved are usually very small (£10-100 per year for a typical property) and in many cases are either zero or a symbolic amount ("a peppercorn"). In the 2011-12 English Housing Survey, amongst those households reporting to pay ground rents, the median household reported annual rents of about £25. In addition, all leases extended under the Leasehold Reform Act of 1993 are set at peppercorn levels. Even in cases where the ground rent is in principle positive, it is often zero in practice, because for the rent to be collected the freeholder has to make a specific written request to the leaseholder. Oftentimes such requests are not made because the amount collected would be too small to cover the administrative costs.

Service and Insurance Charges: Service charges are payments by the leaseholder for services provided by the landlord. These include maintenance and repairs, insurance of the building and, in some cases, provision of central heating, lifts, porterage, estate staff, lighting and the cleaning of common areas. In the 2011-12 English Housing Survey, 46% of leaseholders reported paying a service charge; amongst those households the median annual payment was about £750.

While maintenance costs can be non-trivial, as long as the maintenance is carried out at fair value (the private market cost of the works) service charges do not provide a problem for our analysis, since freeholders would also have to pay for the maintenance of the property. Having the landlord conduct maintenance may even be efficient, because she will likely enjoy significant economies of scale.

A potential problem exists if freeholders might attempt to extract monopoly rents via the service charge, as suggested by some newspaper articles The Observer (2013). We do not, however, believe that this is a likely explanation of the leasehold discounts estimated in the data. The ability to extract rents is severely limited. First of all, under the Commonhold and Leasehold Reform Act 2002 an application can may be made to a Leasehold Valuation Tribunal to challenge the reasonableness of service charges. Secondly, The Commonhold and Leasehold Reform Act 2002 provides a right for leaseholders of flats to force the transfer of the landlord's management functions to a special company set up by them - a "right to manage" company. This does not require the landlord's conset, and significantly limits her ability to extract unreasonable service charges.

Similarly, in some cases the lease requires that the leaseholder insures the property, usually a house, through an insurer nominated or approved by the landlord. The tenant may consider that he can get cheaper insurance from different companies and may be concerned as to the cover provided. The provisions of Section 164 of the Commonhold and Leasehold Reform Act 2002 provide a right for the leaseholder to arrange his own insurance, provided he notifies the landlord.

Leasehold Covenants: A further concern might be that contractual covenants in leasehold deeds place restrictions on leaseholders that reduce the value of the leasehold relative to the freehold. We analyze a large number of covenants from deed titles individually downloaded from the Land Registry website to determine whether or not such contractual restrictions might explain the estimated discounts.[52] In this section, we present examples of the covenants discovered in these titles, after removing any personal identifiers. Many leaseholds do not carry restrictions; others contain only old, out-of-date restrictions, which, while technically still in place, are generally not enforced.[53]

When present, we find four main types of covenants. The first and most common type of covenant involves restrictions on the **broad type of land use**, such as restricting structures to be residential rather than commercial. Usually these are consistent with council zoning regulations, which would also apply to the owners of freeholds:

> No building now or hereafter to be erected on the premises hereby transferred or any part or parts thereof shall at any time hereafter be used for any other purpose than that of private dwellinghouses buildings and appurtenances belonging thereto and no block of flats hotel factory or retail shop or other premises for the sale of goods by retail shall be erected on the premises hereby transferred and that the Purchaser and its successors in title and assigns will not at any time use exercise or carry on or permit to be carried on upon any part or parts of the premises hereby transferred or any buildings for the time being erected or to erected or standing thereon any trade manufacture or business or do any act or thing which may be or grow to be in any way offensive noxious or dangerous to the Vendor or its Superior Lessors or tenants or the owner or tenants of adjoining property forming part of the Vendor's estate or any part thereof and will not use or permit to be used the premises hereby transferred or any buildings erected thereon or any part thereof for the purpose of manufacturing storing selling supplying or distributing either by wholesale or retail ales beers wines spirits or any other intoxicating liquors nor shall any house or building erected or to be erected on the premises hereby transferred or on any part thereof be converted or used for such purposes or used as a cinema or a club or clubs at which intoxicating liquors may be stored sold or supplied.

[52] http://www.landregistry.gov.uk/public/property-ownership allows the download of individual deeds, including any covenants on the land, for a charge of £3 per title.

[53] For example, a leasehold for a flat states that "A Conveyance dated 20 June 1864 made between (1) [Person A] and (2) [Person B] contains restrictive covenants but neither the original deed nor a certified copy or examined abstract thereof was produced on first registration."

Note that while those covenants restrict the use of land and future structures to be residential, there are no further restrictions on the construction of such new residential properties. Some leasehold covenants do place restrictions on the **construction of a new structure**. To the extent that there are such restrictions on new structures, many times they again relate to restrictions placed by the council, and would equally apply to all new structures that freeholders might want to erect (see in particular point 3 of the following leasehold covenant):

> The land tinted pink on the filed plan is subject to the following stipulations contained in a Deed dated 10 August 1923 made between (1) [Person A], (2) [Person B] (3) [Person C].
>
> 1. No church chapel synagogue or other place of public worship or instruction manufacturing premises institution nursing home lunatic asylum sanatorium creche school public motor garage licensed premises theatre cinematograph theatre or other place of amusement shop or business premises shall be erected on the premises and no buildings now or at any time to be erected thereon shall at any time be used except as private dwellinghouses only but no objection shall be made to user of the premises at present erected on the land as a private residential hotel.
> 2. Any dwellinghouse when erected on the said premises shall be of the value of £900 at least in prime cost of materials and labour exclusive of any outbuildings stabling or motor garage.
> 3. The front wall of any dwellinghouses to be erected on the premises shall range and be set back from Poynders Road within the boundary line to be fixed by the London County Council and in accordance with the provisions of the Housing and Town Planning Scheme of the District.

Other, covenants require the permission of the freeholder for certain redevelopments (i.e. placing a structure close to the property edge):

> A Conveyance of the land in this title and other land dated 10 March 1914 made between (1) [Person A] (Vendor) and (2) [Person B] contains the following covenants: Covenant by Purchasers with Vendor his heirs and assigns that the Purchasers their heirs and assigns would not place or suffer to be placed any building whatsoever other than walls or fences under 6 feet in height on any part of the lands thereby conveyed nearer than 30 feet to the road called

> Lambton Road without the previous consent in writing of [Person A] or the person or persons claiming in succession to them.

In general, however, a covenant against the making of improvements without consent is subject to the provision that consent shall not be unreasonably withheld. This was determined by **Section 19(2) of the 1927 Landlord and Tenant Act**:

> In all leases whether made before or after the commencement of this Act containing a covenant condition or agreement against the making of improvements without a licence or consent, such covenant condition or agreement shall be deemed, notwithstanding any express provision to the contrary, to be subject to a proviso that such licence or consent is not to be unreasonably withheld; but this proviso does not preclude the right to require as a condition of such licence or consent the payment of a reasonable sum in respect of any damage to or diminution in the value of the premises or any neighbouring premises belonging to the landlord, and of any legal or other expenses properly incurred in connection with such licence or consent nor, in the case of an improvement which does not add to the letting value of the holding, does it preclude the right to require as a condition of such licence or consent, where such a requirement would be reasonable, an undertaking on the part of the tenant to reinstate the premises in the condition in which they were before the improvement was executed.

As described by Burn, Cartwright and Cheshire (2011), the word "improvements" refers to improvements from the point of view of the tenant, and the statute applies even though what he proposes to do, for example, the demolition of part of the main structure of a building, will demporarily deminish the value of the premises (see *Lambert v Woolworth & Co Otd, 1938*).

The third class of covenants relate to the **joint use of infrastructure** such as access roads:

> The land is subject to the following reservations contained in a Conveyance of the freehold estate in the land in this title and other land dated 10 October 1878 made between (1) [Person A] and (2) [Person B]: Reserving nevertheless to the said [Person A] his heirs and assigns owner or owners for the time being of any messuage to be erected on the adjoining land on the South of the said premises thereby granted the right of using a Drain already constructed under the South side of the back yard of the Southernmost of the said messuages thereby granted to connect the drain from the said messuage so to be erected

> on the adjoining land on the South of the said premises thereby granted as aforesaid with the said Drain the use whereof was thereinbefore granted by the said [Person A] with liberty for the said [Person A] his heirs and assigns tenants or occupiers and his and their servants and workmen at all reasonable times to enter the back-yard of the Southernmost of the said messuages thereby granted for he purpose of connecting and repairing such Drain such Drain in the said backyard to be kept in repair when and so soon as the same should be used by the said [Person A] his heirs or assigns tenants or occupiers at the joint expense of the said [Person A] his heirs and assigns and of the said [Person B] his heirs and assigns and each of them would pay to the other of them on demand one moiety of the expenses incurred by the other of them in repairing such last mentioned Drain.

Unless there is specific agreement to the contrary, a tenant is free to grant his interest to a third party, either by assignment or by underlease, as described in Burn, Cartwright and Cheshire (2011). A fourth set of covenants we sometimes encountered therefore requires leaseholders to obtain the freeholder's permission to **sublet the property**, i.e. to rent it out to somebody else. These requirements usually stipulate that the freeholder cannot "unreasonably withhold" consent to a sublet, and sometimes allow the freeholder to charge a fee for registering a sublet. These terms for subletting property are regulated in **Section 19(1) of the 1927 Landlord and Tenant Act**, which provides as follows:

> In all leases whether made before or after the commencement of this Act containing a covenant condition or agreement against assigning, under-letting, charging or parting with possession of demised premises or any part thereof without licence or consent, such covenant condition or agreement shall, notwithstanding any express provision to the contrary, be deemed to be subject
>
> 1. to a proviso to the effect that such licence or consent is not to be unreasonably withheld, but this proviso does not preclude the right of the landlord to require payment of a reasonable sum in respect of any legal or other expenses incurred in connection with such licence or consent; and
> 2. (if the lease is for more than forty years, and is made in consideration wholly or partially of the erection, or the substantial improvement, addition or alteration of buildings, and the lessor is not a Government department or local or public authority, or a statutory or public utility company) to a proviso to the effect that in the case of any assignment, under-letting,

> charging or parting with the possession (whether by the holders of the lease or any under-tenant whether immediate or not) effected more than seven years before the end of the term no consent or licence shall be required, if notice in writing of the transaction is given to the lessor within six months after the transaction is effected.

Furthermore, the Landlord and Tenant Act 1988 places on the landlord the burden of showing that any refusal or the imposition of any conditions was reasonable. It also gives a tenant the right to sue for damages suffered as a result of a landlord's unreasonable refusal. Subsequent common law cases have further regulated the maximum fee that freeholders can charge for the granting of approval for a sublet. In *Holding and Management (Solitaire) Limited vs. Cherry Lilian Norton (LRX/33/2011)*, the court decided that a fee in excess of £40 + VAT was not merited.

A.2 Institutional Appendix - Singapore

Residential properties in Singapore can be classified into land titles or strata titles. Land title properties occupy land that is exclusive to the owner (like a detached house), whereas a strata title comprises units in cluster housing (flats or apartments) or in condominium developments. Owners of strata properties enjoy exclusive title only to the airspace of their individual unit. The land that the development is built on is shared by all the owners of the project, based on the share of the strata title unit owned by each owner. Owners are free to sell their individual unit. In order to sell the land, they will have to go via an "en bloc" sale, which requires a minimum of 80% of the owners' consent.[54]

A large fraction of the Singaporean housing stock consists of Housing and Development Board (HDB) properties, mostly in the form of flats. In total over 80% of Singapore's population lives in HDB flats, and 90% of them are fully owned. The HDB flats are part of a state-subsidized home-ownership program and leases are often granted at below market values. We exclude these properties from our analysis and focus instead on the private market, where transaction prices reflect market values of the properties.

Property taxes are independent of the form and duration of ownership. Property taxes are levied on the *Annual Value* (AV), the tax-authority assessed 1-year rental income of the property. For rental properties, the tax rate is set at 10% of AV; for owner-occupied properties, it rises from 0% on the first \$6,000 to a marginal rate of 6% for AVs exceeding

[54] 80% consent is necessary if the development is at least 10 years old and 90% consent is necessary if the development is less than 10 years old.

$65,000.[55] The rental income, and therefore the Annual Value, of a property is unaffected by the length of the lease under which the property is owned. Property transactions are also subject to stamp duty irrespective of the form and duration of ownership.[56] As with the U.K., the progressive nature of the tax increases the relative value of short-duration leasehold properties who are cheaper and therefore taxed at the lower marginal rate.

Singapore allows homebuyers to use their pension contributions to pay off their mortgage. Recently, it is also allowed to use such contributions to pay off certain portion of down payment. However, for any leasehold property, if the number of years remaining is less than 60 years at the time of transaction, homebuyers are not allowed to use pension contributions to buy their properties. Consistent with this, banks have a similar restrictions for mortgage lending.

[55] Starting from January 1, 2014, property taxes were made more progressive. For details see: http://www.iras.gov.sg/irasHome/page04.aspx?id=2094. This is after the end of our sample, and should thus

[56] Stamp duties are transaction taxes, and are assessed on the purchase value of the property. The first $180,000 are assessed at 1%, the next $180,000 at 2% and each additional increase in the sales prices at 3%. See http://www.iras.gov.sg/irasHome/page04.aspx?id=8748fordetails.

A.3 Data and Empirical Appendix

A.3.1 U.K. Leasehold Discounts - Houses

In Section 2.1.3 we analyzed price differences between leaseholds of varying maturity and freeholds for flats in the U.K. In this section we show that the estimated price differences between leaseholds and freeholds are, if anything, larger in the transaction sample for U.K. houses. The bottom panel of Table 1 reports the composition of our sample of houses. We observe just above 6.5 million transactions between 2004 and 2013, almost all of which (95%) are transactions of freeholds. Most of the remaining leaseholds are concentrated at maturities below 125 years or above 700 years: around 300,000 transactions, or 4% of the sample, are for leaseholds with 700 or more years remaining. The number of transactions for shorter leases is much smaller, with around 0.8% below 125 years and only 0.2% between 125 and 200 years. Given the lack of data for intermediate maturities for houses, we focus on the very-long maturities (700+ years remaining) and the short maturities (less than 125 years remaining) when analyzing house transactions. For houses, leaseholds are more geographically concentrated, clustering around Manchester and Newcastle.[57] Overall, relative to the transaction sample for flats, for transactions of houses we have less variation across contracts, in particular for leases between 125 years and 700 years. This was the reason to focus on flats in the main body of the paper.

In this section we estimate the relative prices paid for leaseholds of varying remaining duration and freeholds for houses in England and Wales. For houses, given the lack of observations for intermediate maturities, we construct the following three *MaturityGroups* for leaseholds: 80-99 years, 100-124, and 700+ years groups. We then estimate regression (A.1) below. The unit of observation is a transaction i of a property of type g (detached, semi, terraced) in 3-digit post code h at time t. We assign each leasehold with remaining maturity T_i to one of the $MaturityGroup_j$ buckets depending on the number of years remaining on the lease at the point of sale. The excluded category are freeholds, so that the β_j coefficients capture the log-discount of leaseholds with that maturity relative to otherwise similar freeholds.

$$log(Price_{i,h,t,g}) = \alpha + \sum_{j=1}^{J} \beta_j \mathbf{1}_{\{T_i \in MaturityGroup_j\}} + \gamma Controls_i + \xi_h \times \psi_t \times \phi_g + \epsilon_{i,h,t,g} \quad \text{(A.1)}$$

Appendix Table A.2 shows the results. The estimated discounts between leaseholds

[57] However, the overall number of transactions for houses is large, so that we have within postcode variation in lease type in most postcodes in our sample, even if one contract type comprises the majority of the sample.

and freeholds are larger for houses than for flats: leaseholds of 80-99 years remaining length trade at a discount of 31% relative to freeholds, and leaseholds with 100-124 years remaining trade at a 26% discount. Very long leaseholds with more than 700 years remaining trade for a small discount of around 1%. While larger in magnitude, the results are in line with the results for flats, though they are less informative given the limited use of leaseholds for houses as well as the geographic concentration of the leaseholds discussed above.

A.3.2 Average Real Housing Returns and Rental Growth

In this section we estimate r and g for the U.S., the U.K. and Singapore. We briefly describe our methodology and findings, and provide the details of the data and estimation procedure in section A.3.2.2 below. We employ two complementary approaches to estimating average returns to housing. The first approach, which we call the balance-sheet approach, is based on the total value of the residential housing stock and the total value of housing services consumed (the dividend from that stock). We obtain this information from countries' national accounts.[58] We control for the growth of the housing stock over time in order to back out the return series for a representative house. The second approach, which we label the price-rent approach, starts from the price-rent ratio estimated in a baseline year and constructs a time series of returns by combining a house price index and a rental income index. This approach focuses on a representative portfolio of houses and, therefore, does not need to correct for changes in the housing stock. After adjusting for inflation, both methods provide estimates of the gross real returns to housing ($E[R^G]$). To compute net returns, we subtract maintenance costs and depreciation (δ) and any tax-related decreases in return (τ). We estimate net returns as $r = E[R] = E[R^G] - \delta - \tau$.

The top panel of Table 8 presents the estimated average housing returns for the U.S., England-and-Wales, and Singapore. Our estimates for housing returns in the U.S. follow Favilukis, Ludvigson and Van Nieuwerburgh (2010).[59] While U.S. housing returns are not the focus of this paper, they provide a useful benchmark because they have been the subject of an extensive literature, including Gyourko and Keim (1992), Flavin and Yamashita (2002), Lustig and Van Nieuwerburgh (2005) and Piazzesi, Schneider and Tuzel (2007). The balance-sheet and the price-rent approaches provide similar estimates for the

[58] To determine the total consumption of housing services, these measures impute the value of the owner-occupied equivalent rents, the housing services consumed by individuals from living in their own house. See Mayerhauser and Reinsdorf (2006) and McCarthy and Peach (2010) for a description of the construction of these measures.

[59] We thank Stijn van Nieuwerburgh for sharing the data and for insightful discussions on estimating housing returns.

average annual real gross return ($E[R^G]$): 10.3% and 10.7% respectively. We calibrate the impact of maintenance and depreciation (δ) at 1.5% and the property tax impact τ at 0.67%.[60] We conclude that average real net returns in the U.S. housing market are between 8% and 8.5%. This is similar to the estimates in Flavin and Yamashita (2002), who find a real return to housing of 6.6%, and Favilukis, Ludvigson and Van Nieuwerburgh (2010), who find a real return of 9-10% before netting out depreciation and property taxes.

Column three and four in Table 8 report our estimates for the Singaporean housing market. The balance-sheet and price-rent approaches provide similar estimates for the average annual real gross return ($E[R^G]$): 10.3% and 10.4%, respectively. We assume the cost of maintenance and depreciation to be 1.5%, in line with the estimates for the U.S., and the property tax impact to be 0.5%.[61] A conservatively low estimate of the real net returns in the Singapore housing market is therefore between 8.3% and 8.4%.

The two rightmost columns of Table 8 report the estimates for the housing market in England and Wales. The balance-sheet and the price-rent approaches provide similar estimates for the average annual real gross return ($E[R^G]$): 12.5% and 10.9%, respectively. We maintain the calibration for the cost of maintenance and depreciation at 1.5%. There are no property taxes to be considered in England and Wales. Average real net returns in the U.K. housing market are approximately $9 - 11\%$.

Overall, the estimates show that real expected returns for housing are between 8% and 10% for all countries in our international panel. These estimates are in line with the existing literature, and robust to the different methodologies.[62] Our estimates for the U.S. and England-and-Wales are consistent with the notion that average house price growth

[60] Malpezzi, Ozanne and Thibodeau (1987) provide an overview of the literature on depreciation. For example, (Leigh, 1980) estimates the annual depreciation rate of housing units in the U.S. to be between 0.36% and 1.36%. Depreciation is also a key calibration parameter for much of a recent literature in macroeconomics that considers households' portfolio and consumption decisions with housing as an additional asset. Cocco (2005) chooses a depreciation rate equal to 1% on an annual basis; Díaz and Luengo-Prado (2008) include an annual depreciation rate of 1.5%. Property taxes in the U.S. are levied at the state level and, while there is variation across states, are generally around 1% of house prices. Property taxes, however, are deductible from federal income tax. We assume that the deductibility reflects a marginal U.S. federal income tax rate of 33%. The net impact is therefore $(1 - 0.33) * 0.01 = 0.67\%$.

[61] Singapore levies a 10% annual tax on the estimated rental income of the property. A lower tax rate applies to owner-occupied properties (6%), but we use the more conservative (higher) rate for rental properties. See section 1.2 for details. The tax impact on returns is the tax rate times the average rent-price ratio, estimated at 5%. Hence, $\tau = 0.1 * 0.05 = 0.5\%$.

[62] We also note that since most movements in rent-price ratios are driven by movements in house prices and not by movements in rents, see Shiller (2007), our estimates of returns are relatively unaffected by the time period chosen. For example, since 2013 rent-price ratios in the U.S. have declined to approximately their 2000 levels (see Figure A.31), ending the sample in 2005 would have produced a slightly lower average rent-price ratio. However, focusing on that period would also exclude the house price crash from our estimates of capital gains, thus leading to higher estimated average capital gains. In the overall estimates of expected returns, the higher estimated capital gains would be offset by a lower estimated rent-price ratio.

over extended periods of time is relatively low, as argued by Shiller (2006), and the key driver of real housing returns is the high rental yield. Our estimated average capital gains are positive but relatively small (even for Singapore where they are the highest) despite focusing on samples and countries that are often regarded as having experienced major growth in house prices.

A.3.2.1 Real Rental Growth

In order to calibrate the parameter governing rent growth (g), we estimate the average growth rate of rental income, obtained directly from rental indexes. The national accounts and the rental index provide similar growth rate estimates on the sample where both are available.

The estimated real growth rate of rents is close to zero. For the U.S., our estimate (0.2%) is in line with the estimates of Campbell et al. (2009) that obtain a median growth rate of 0.4% per year. We obtain a similarly low estimate (0.2%) of average annual rental growth for Singapore, while the U.K. estimate is somewhat higher at 0.7%. As for the case of real average house price growth, our estimates of small-to-negligible real rent growth are in line with Shiller (2006). In our baseline estimates, we calibrate g to be 0.2%.

A.3.2.2 Details on Estimation Procedures

This section describes the methodology and data used to compute average real returns and rent growth for residential properties. We report the details of the calculations in an online appendix.

The balance-sheet approach Following Favilukis, Ludvigson and Van Nieuwerburgh (2010), this approach uses information about the value of the stock of residential real estate to estimate the value (price) of housing and total household expenditure on housing as a measure of the value of rents in each period. Since we are only interested in the return to a representative property, we need to control for changes in the total housing stock. We proxy for the change in the stock by population growth, assuming that at least over long periods the per capita stock of housing is constant. We derive the gross return to housing in each period as:

$$R_{t+1}^{G} = \frac{V_{t+1}^{H} + CE_{t}^{H}}{V_{t}^{H}} \frac{\pi_t}{\pi_{t+1}} \frac{L_t}{L_{t+1}},$$

where V^H is the value of the housing stock, CE^H is the household expenditure on housing,

π is the CPI price level index, and L is population.

- For the U.S. we follow Favilukis, Ludvigson and Van Nieuwerburgh (2010) and use data from the Flow of Funds (obtained from the Federal Reserve Board and the Federal Reserve Bank of St. Louis). For the value of the housing stock we sum the value of two series: owner-occupied real estate and tenant-occupied real estate (FL155035005, FL115035023) from the Flow of Funds. From the Federal Reserve Bank of St. Louis we obtain: (i) household expenditure on housing in each period, series number DHUTRC1A027NBEA of the National Income and Product Accounts (personal consumption expenditures - services: housing and utilities); (ii) Population estimates (POP); and (iii) the Consumer Price Index (U.S.ACPIBLS).

- For the U.K., using the same procedure, we combine the value of the total stock of housing (series CGRI) and the total expenditures on housing (series ADIZ) from the National Accounts (available from the Office of National Statistics). From the same source, we obtain the CPI (series D7BT). We adjust for the change in the stock of housing using the population growth series from ONS for England and Wales.

- We use a similar procedure for Singapore. From the National Accounts (from singstat.gov.sg), we obtain the value of the private residential stock of housing (series M013181.1.1.1 P017199) and the private consumption expenditure on housing and utilities (series M013131.1.4 P017135). We obtain the series for the population growth (that proxies for the change in the stock of housing wealth) from the World Bank (series SP.POP.GROW). Finally, we obtain the CPI series from the National Statistical Office (singstat.gov.sg).

The price-rent approach This approach constructs a time series of returns by combining information from a house price index, a rent index, and an estimate of the price-to-rent ratio in a baseline year. Without loss of generality suppose we have the rent-to-price ration at time $t = 0$. We can derive the time series of the rent-to-price ratio as:

$$\frac{P_t}{D_{t+1}} = \frac{P_t}{P_{t-1}} \frac{D_t}{D_{t+1}} \frac{P_{t-1}}{D_t}; \qquad \frac{P_0}{D_1} \quad given.$$

where P is the price index and D the rental index. Notice that, given a baseline year $\frac{P_0}{D_1}$, only information about the growth rates in prices and rents are necessary for the calculations. We then compute real returns using the formula:

$$R^G_{t+1} = \left(\frac{D_{t+1}}{P_t} + \frac{P_{t+1}}{P_t} \right) \frac{\pi_t}{\pi_{t+1}}.$$

- For the U.S. we follow Favilukis, Ludvigson and Van Nieuwerburgh (2010) and use the Case-Shiller 10-city house price index (series SPCS10RSA from the Federal Reserve Bank of St. Louis), and compute rent growth using the BLS shelter index (the component of CPI related to shelter, item CU.S.R0000SAH1 from the Federal Reserve Bank of St. Louis). However, differently from Favilukis, Ludvigson and Van Nieuwerburgh (2010), we choose 2012 as a baseline year for the rent-price ratio, which is estimated at 0.1, because of the availability of high quality data for that year. We obtained two independent estimates for the rent-price ratio in the base year of 2012. The first estimate is the price-rent ration implied by the balance-sheet approach. The second estimate is a direct estimate obtained using data by the real estate portal Trulia. Figure A.30 shows the distribution of rent-price ratios across the 100 largest MSAs provided by Trulia.[63] Both independent estimates imply a rent-price ratio of 10% in 2012. Figure A.31 suggests that these rent-price ratios are close to their long-run average.

- For Singapore we obtain a time series of price and rental indices for the whole island from the Urban Redevelopment Authority (the official housing arm of the government: ura.gov.sg).

  To estimate the baseline rent-price ratio, we use data from for-sale and for-rent listings provided by iProperty.com, Asia's largest online property listing portal. We observe approximately 105,000 unique listings from the year 2012, about 46% of which are for-rent listings. To estimate the rent-price ratio we run the following regression which pools both types of listing, which follows a similar methodology as Figure A.30 in the construction of rent-price ratios for the U.S.:

$$\ln\left(ListingPrice\right)_{i,t} = \alpha + \beta_i ForRent_i + \gamma Controls_{i,t} + \epsilon_{i,t} \tag{A.2}$$

  The dependent variable, *ListingPrice* is equal to the list-price in "for-sale" listings, and equal to the annual rent in "for-rent" listings. $ForRent_i$ is an indicator variable that is equal to one if the listing is a for-rent listing. The results are reported in Table A.5. In column (1) we control for postal code by quarter fixed effects. The estimate coefficient on β_i suggests a rent-price ratio of $e^{\beta_i} = 4.5\%$. In columns (2) - (4) we also control for other characteristics of the property, such as the property

[63] We thank Jed Kolko and Trulia for providing these data. Trulia observes a large set of both for-sale and for-rent listings. The rent-price ratio is constructed using a MSA-level hedonic regression of log(price) on property attributes, zip code fixed effects, and a dummy for whether the unit is for sale or for rent. The rent-to-price ratio is constructed by inverting the exponent of the coefficient on this dummy variable.

type, the number of bedrooms, bathrooms as well as the property type, size, age and the floor. In columns (3) and (4) we tighten fixed effects to the month by postal code level and the month by postal code by number of bedrooms level respectively. In all specifications the estimated rent-price ratio fro 2012 is 4.5%. Finally, note that if we instead used the rent-price ratio obtained from the Balance Sheet approach as a baseline estimate in 2012, we would obtain a higher total return (as the baseline in 2012 would be 6% rather than 4.5%). We choose 4.5% to be as conservative as possible.

- For England and Wales we use the house price index from the U.K. Land Registry to compute price appreciation and we use the CPI component "Actual rents for housing" (series D7CE) from the Office of National Statistics as a rental index. As a baseline we used the 6% rent-price ratio in 2012 obtained from the balance-sheet approach.

A.3.3 The Riskiness of Housing - Details

This section provides the details underlying the analysis carried out in Section 3. Section A.3.4 will provide additional evidence for the riskiness of housing. We are deeply indebted to a number of researchers, statistical agencies, and scholars that have either made their data available online, shared it with us on request, or have in general been available to discuss long-term house prices and rent behavior with us. For convenience to future scholars, a replication dataset with all the raw data series for this section of the paper is available on our websites. The original sources of each series are acknowledged here and should be cited in future use of our replication dataset.

Table A.6 reports the availability of house price data and the associated financial crises are rare disasters. The second column in Table A.6 shows the time coverage of house price indices country by country. We have often been able to go far back in time; for example, we sourced data as far back as 1819 for Norway, 1840 for France, and 1890 for the U.S. The third and fourth column of the table report dates of banking crises or consumption rare disasters if any occur for the country in the time period provided in the first column. Banking crises dates for all countries, except Singapore, Belgium, Finland, Ireland, New Zealand, South Korea, and South Africa, are from Schularick and Taylor (2012). Banking crises dates for the countries not covered by Schularick and Taylor (2012) are from Reinhart and Rogoff (2009).[64] Rare disasters dates in the last column of the table

[64] For this second set of countries/dates, we have also consulted Bordo et al. (2001) that confirms all dates in Reinhart and Rogoff (2009) except for 1986 for South Korea and for 1989 for South Africa.

are the year of the trough in consumption during a consumption disaster as reported by Barro et al. (2008). We note that Ireland and South Africa are not covered by Barro et al. (2008).

For each country we obtained the longest continuous and high-quality time series of house price data available. To make the data comparable across countries and time periods, we focus on real house prices at an annual frequency. Finally, to increase historical comparability across time within each time series, for each country we report for the entire time period the index for the unit of observation (for example, a city) for which the longest possible high quality time series is available. For example, since a house price index for France is only available since 1936, but a similar index is available for Paris since 1840, we focus on the Paris index for the entire history 1840-2012. We stress, however, that for each index and country we have carried out an extensive comparison analysis with other indices and in particular with indices that are available for the most recent time period in order to ensure that we are observing consistent patterns in the data. We detail here the sources for each of the 21 countries in our sample:

- **Australia**: Real annual house price indices are from Stapledon (2012). For our analysis, we use the arithmetic average of the indices (rebased such that 1880 = 100) for Melbourne and Sydney.

- **Belgium, Canada, Denmark, Finland, Germany, Japan, Ireland, Italy, New Zealand, South Africa, South Korea, and Spain**: Real annual house price indices are from the Federal Reserve Bank of Dallas.[65] The sources and methodology are described in Mack and Martínez-García (2011*a*).

- **France**: Nominal annual house price index and CPI are available from the Conseil Général de l'Environnement et du Développement Durable (CGEDD).[66] We obtain the real house price index by deflating the nominal index by CPI. For our analysis, we use the longer time series available for the Paris house price index.

- **Netherlands**: Nominal annual house price index for Amsterdam and CPI for the Netherlands are available from Eichholtz (1997); Ambrose, Eichholtz and Lindenthal (2013).[67] We obtain the real house price index by deflating the nominal index by CPI.

[65]The data are available at: http://www.dallasfed.org/institute/houseprice/, last accessed February 2014.

[66]http://www.cgedd.developpement-durable.gouv.fr/les-missions-du-cgedd-r206.html, last accessed February 2014.

[67]Part of the data are are available on Eicholtz website at: http://www.maastrichtuniversity.nl/web/Main/Sitewide/Content/EichholtzPiet.htm, last accessed February 2014.

- **Norway**: Nominal annual house price index and CPI are from the Norges Bank.[68] We obtain the real house price index by deflating the nominal index by CPI.

- **Singapore**: Nominal annual house price index for the whole island is from the Urban Redevelopment Authority (http://www.ura.gov.sg). CPI is from Statistics Singapore. We obtain the real house price index by deflating the nominal index by CPI.

- **Sweden**: Nominal house price index for one-or-two-dwelling building and CPI are from Statistics Sweden. We obtain the real house price index by deflating the nominal index by CPI.

- **Switzerland**: nominal house price index is available by Constantinescu and Francke (2013). Among the various indices the authors estimate, we focus on the local linear trend (LLT) index. The data are available for the period 1937-2007. We update the index for the period 2007-2012 by using the percentage growth of the house price index for Switzerland available from the Dallas Fed.[69]

- **U.K.:** Annual nominal house price data are from the Nationwide House Price Index. We divide the nominal index by the U.K. Office of National Statistics "long term indicator of prices of consumer goods and services" to obtain the real house price index. The Nationwide index as a missing value for the year 2005, for that year we impute the value based on the percentage change in value of the house price index produced by the England and Wales Land Registry.

- **U.S.**: Real annual house price data are originally from Shiller (2000). Updated data are available on the author's website.[70]

For all countries except Ireland the real annual consumption data are from Barro et al. (2008) and available on the authors' website.[71] For Ireland the data on consumption is from Central Statistics Office Ireland.

A.3.4 The Riskiness of Housing - Additional Evidence

In this section we provide additional evidence for the riskiness of housing to complement the analysis in Section 3.

[68] http://www.norges-bank.no/en/price-stability/historical-monetary-statistics/, last accessed February 2014.

[69] This source is described in the second bullet point above.

[70] Available at: http://aida.wss.yale.edu/~shiller/data.htm, last accesses February 2014.

[71] Available at: http://rbarro.com/data-sets/, last accessed February 2014.

Figure A.32 shows the time series of house prices and marks with shadowed bands years of crisis for the UK and Singapore.[72] The pattern of house price movement during crises in these two countries is similar to the average pattern described in Section 3. For example, house prices peak and then fall during major crises in the sample: the 1974-76 and 1991 banking crises in the UK, and the 1982-83 banking crisis as well as the 1997 Asian financial crisis in Singapore.[73] Similarly, both countries experience a drop in house prices during the 2007-08 global financial crisis.

Figure A.33 shows the performance of house prices during major wars, namely World War I and II (WWI and WWII). In both cases time zero is defined to be the start date of the war period, 1913 and 1939 for WWI and WWII respectively. The dotted line tracks house prices for 5 countries for the duration of WWI (1913-1918).[74] House prices fell throughout the war with a total fall in real terms close to 40%. Similarly, the solid line tracks house prices for 6 countries for the duration of WWII (1939-1945).[75] House prices fell by 20% in real terms from 1939 to 1943 and then stabilized for the last two year of the war, 1944-45. Overall we find wars to be periods of major falls in real house prices, thus contributing to the riskiness of housing as an asset.

We also provide a robustness check for the correlation between house price growth and measures of economic activity. The main body of the text focused on consumption growth in 9. By contrast, Table 9 uses data from Mack and Martínez-García (2011*a*) to report the correlation between annual real house price growth and personal disposable income in a panel of 21 developed and emerging countries. The average correlation is 0.37, with a minimum of 0.05 for Luxembourg and a maximum of 0.63 for Spain. Overall, this evidence further corroborates the fact that housing returns are risky.

Figure A.34 plots the growth rates of rents and personal consumption expenditures (PCE) in the U.S. since 1929. In periods of falling PCE, in particular the Great Depression, rents also fell noticeably. The bottom panel shows that there is a (weak) positive relationship between the growth rates of rents and personal consumption expenditures. This suggests that housing rents tend to increase when consumption increases and the marginal utility of consumption is low.

[72] All crises dates are from Reinhart and Rogoff (2009) except the periods 1997-98 and 2007-08 for Singapore. The latter dates have been added by the authors and are commonly documented to correspond to the Asian financial crisis of 1997-98 and the global financial crisis of 2007-08.

[73] The 1984 banking crisis in the UK proves the sole exception: house prices increase during this crisis.

[74] Due to data availability for house price indices during this period, the countries included are Australia, France, Netherlands, Norway, and the United States.

[75] Due to data availability for house price indices during this period, the countries included are Australia, France, Netherlands, Norway, Switzerland, and the United States.

A.4 Theoretical Appendix

A.4.1 The Stochastic Discount Factor

Consider a claim to the risky rent at time T, denoted D_T. The present value at time t is the expected dividend $E_t[D_T]$ discounted with some discount factor $R_{t,t+T}$:

$$P_t^{D_T} = \frac{E_t[D_T]}{R_{t,t+T}}. \tag{A.3}$$

The price of a safe security that pays 1 for sure at maturity T is: $P_t^{1_T} = 1/R^f_{t,t+T}$, where $R^f_{t,t+T}$ is the total return on the safe security when held to maturity. Since the rent D_T is risky, and risky cash flows are discounted at a higher rate than if they were safe, we have $R_{t,t+T} > R^F_{t,t+T}$. We can decompose $R_{t,t+T}$ into a discount factor that would be applied even if D_T were certain, and an additional discount that compensates the agents for risk, the risk premium $RP_{t,t+T}$: $R_{t,t+T} = R^f_{t,t+T} + RP_{t,t+T}$. Asset pricing theory relates the discount factors $R_{t,t+T}$ and $R^f_{t,t+T}$ to a "stochastic discount factor" (SDF) $\xi_{t,t+T}$ that reflects marginal utility in different states of the world. Assets are priced according to:

$$P_t^{D_T} = E_t[\xi_{t,t+T} D_T], \tag{A.4}$$

The values of $R_{t,t+T}$, $RP_{t,t+T}$, and $\xi_{t,t+T}$ are related via the formulas below:

$$\begin{aligned} R^f_{t,t+T} &= E_t[\xi_{t,t+T}]^{-1}, \\ RP_{t,t+T} &= -\frac{Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}]}{Var[\xi_{t,t+T}]} \frac{Var[\xi_{t,t+T}]}{E_t[\xi_{t,t+T}]} \equiv \beta_{t,t+T}\lambda_{t,t+T}. \end{aligned}$$

The risk-free component of the discount factor is related to the inverse of the expectation of the long-term SDF, i.e. long-term marginal utility growth. The risk premium has the opposite sign to the covariance between the stochastic discount factor and the rent, $Cov_t[\xi_{t,t+T}, D_T]$.[76] A claim that pays a higher rent in states of the world when extra resources are less valuable, i.e. when marginal utility $\xi_{t,t+T}$ is low, is less desirable and thus discounted at a higher rate. Such an asset is risky, and its risk premium is positive. The risk premium ($RP_{t,t+T}$) can be further decomposed into an asset-specific "quantity of risk" term ($\beta_{t,t+T}$), which summarizes how strongly the payoff co-varies with the stochastic discount factor, and a common "price of risk" term ($\lambda_{t,t+T}$), that only depends on $\xi_{t,t+T}$

[76] Recall that in this case $Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}] = Cov_t[\xi_{t,t+T}, D_T]$ because $\tilde{R}_{t,t+T} = D_T/P_t^{D_T}$ is the stochastic return on investing in the risky asset.

and summarizes the compensation required for each unit of risk at that horizon.

We now provide detailed derivations. Starting with the fundamental valuation equation $P_t^{D_T} = E_t[\xi_{t,t+T} D_T]$ and the definition of return $\tilde{R}_{t,t+T} = \frac{D_T}{P_t^{D_T}}$, we have:

$$1 = E_t[\xi_{t,t+T}\tilde{R}_{t,t+T}] = E_t[\xi_{t,t+T}]E_t[\tilde{R}_{t,t+T}] + Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}].$$

Re-arranging we obtain:

$$E_t[\tilde{R}_{t,t+T}] = E_t[\xi_{t,t+T}]^{-1}\left(1 - Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}]\right) = R^f_{t+t+T} - Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}]E_t[\xi_{t,t+T}]^{-1},$$

where the last equality follows from the definition $R^f_{t+t+T} \equiv E_t[\xi_{t,t+T}]^{-1}$. Finally, we re-arrange the definition of returns, take conditional expectations, and substitute in the above derivation for expected returns to write:

$$\begin{aligned}
P_t^{D_T} =& \frac{E_t[D_T]}{E_t[\tilde{R}_{t,t+T}]} \\
=& \frac{E_t[D_T]}{R^f_{t+t+T} - Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}]E_t[\xi_{t,t+T}]^{-1}} \\
=& \frac{E_t[D_T]}{R^f_{t+t+T} - \frac{Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}]}{Var_t[\xi_{t,t+T}]}\frac{Var_t[\xi_{t,t+T}]}{E_t[\xi_{t,t+T}]}},
\end{aligned}$$

which provides the the main relations by defining:

$$\begin{aligned}
R_{t,t+T} &\equiv E_t[\tilde{R}_{t,t+T}]; \\
RP_{t,t+T} &\equiv \beta_{t,t+T}\lambda_{t,t+T}; \\
\beta_{t,t+T} &\equiv -\frac{Cov_t[\xi_{t,t+T}, \tilde{R}_{t,t+T}]}{Var_t[\xi_{t,t+T}]}; \\
\lambda_{t,t+T} &\equiv \frac{Var_t[\xi_{t,t+T}]}{E_t[\xi_{t,t+T}]}.
\end{aligned}$$

Equation 6 can then be derived by noticing that $P_t - P_t^T$, the difference in price between the freehold and the leasehold of maturity T, is the price today of a claim to the freehold T periods from now. In brief, it is a claim today to a single payoff, P_{t+T}, T periods from now.

A.4.2 Leading Asset Pricing Models

In this appendix we consider in more detail the predictions of leading asset pricing models for the evaluation of long-run risky cash flows and the implied leasehold discounts. We discuss the models briefly, focussing on the most important elements for the valuation of long-dated claims to housing. When calibrating the models we deviate as little as possible from the original papers' calibrations of the stochastic discount factor and cash-flows. In each model, we calibrate housing to be a risky asset with an average growth rate of rents of 0.7% and an exposure to risk that ensures an expected return of 6.5%.

In the long-run risk model of Bansal and Yaron (2004) agents have a preference for early resolution of uncertainty and are concerned about shocks that persistently affect the growth rate of consumption.[77] Therefore, agents dislike claims to very long-term cash flows that are exposed to these long-run risks.[78] The model matches the expected return to housing only if housing is exposed to long-run risks. The model also implies that leaseholds with higher maturity are more exposed to long-run risks, and command higher risk premia.[79] This upward sloping term structure of risk premia contributes to generating smaller discounts for leaseholds relative to freeholds compared to the constant-discount-rate model. Appendix Figure A.38, which separates out risk-free yields and annualized risk premia, confirms the analysis of Hansen, Heaton and Li (2008) who show that the result is driven by risk premia that increase with maturity.[80]

In the external habit model of Campbell and Cochrane (1999) agents care about their surplus consumption relative to a habit level, which itself depends on the history of aggregate consumption.[81] Negative shocks to consumption, with which rents are corre-

[77]We calibrate the model following the parametrization of Bansal and Yaron (2004). The baseline calibration of the risky asset in that paper implies an expected return of 6.5% a year and, consequently, we maintain the same calibration here. We only modify the average growth rate of cash flows (rents) to match the observed 0.7% annual growth rate of rents as in our baseline calibration.

[78]Dew-Becker and Giglio (2013) show that half the total price of risk in the long-run risk model comes from fluctuations in consumption with cycles longer than 230 years and three quarters of the risk prices come from fluctuations longer than 75 years. These horizons correspond closely to the maturities of the leaseholds we consider in this paper.

[79]A similar result obtains when agents have power utility but are ambiguity averse, as in Hansen and Sargent (2001). When the agent has a preference for robustness, she can be viewed as having a reference distribution for the relevant shocks (the true distribution) and a worst-case distribution, which is what she uses to price assets. Under the worst-case distribution she places relatively more weight on bad states of the world, which correspond to states with persistently low consumption growth. Therefore, the model has similar asset pricing implications to the long-run risk model.

[80]We calibrate the yield $r^f_{t,T}$ and the total per-period discount rate for a T-maturity asset r_t using the model, and report $rp_{t,T}$ as the difference between the two. As mentioned in the previous section, this per-period $rp_{t,T}$ does not have the interpretation of an expected return, which would correspond to the expectation of a holding period return for one period.

[81]We calibrate the model following the parametrization of Campbell and Cochrane (1999). We impose an

lated, induce increases in risk premia because they bring current consumption closer to the habit level. Long-term claims, due to their high duration, are particularly exposed to these shocks and are therefore particularly risky. The model implies an upward sloping term structure of risk premia that contributes to generate low discounts for leaseholds compared to freeholds. Appendix Figure A.38 confirms this intuition by showing that while risk-free yields are constant across maturities, risk premia are increasing in maturity.

In the rare disasters model of Barro (2006) and Gabaix (2012) consumption growth is subject to rare but large negative shocks, the disasters.[82] Agents dislike assets that are exposed to these disasters. While the presence of rare disasters increases risk premia, it does so uniformly across maturities because claims to cash flows at all horizons are equally exposed to the disaster risk. Therefore, discount rates will be the same at all horizons and equal to the average return (6.5%). These high constant-discount rates produce leasehold price discounts compared to freeholds similar to those of the constant-discount-rate model.

Appendix Figure 5 shows the discounts for long-dated leaseholds relative to freeholds implied by these three leading models together with those observed in the data. In all cases, the models produce discounts similar, or even smaller, to the constant-discount-rate model discussed in Section 4.1.

A.4.3 Details on Hyperbolic-Exponential Discounting

We include here details for the derivations in Section 5.1 of the paper. First, let us focus on a model of pure hyperbolic discounting. In continuous time, the hyperbolic discount function is simply $\frac{1}{1+\kappa s}$ where $\kappa > 0$ is the subjective hyperbolic parameter. To gather intuition, assume that rents were constant at D. Let us value the T lease contract. For simplicity consider the $t = 0$ starting condition.

$$P_t^T = \int_0^T \frac{1}{1+\kappa\, s} D ds = D \frac{\ln(1+\kappa\, T)}{\kappa}.$$

The obvious problem with this type of discounting when applied to longer term assets is that the valuation of claims diverges (even without dividend growth) as the horizon T

average growth rate of rents of 0.7% per year, and a correlation of rent growth and consumption growth of 0.27 to ensure that expected returns on housing are 6.5%.

[82]We calibrate the model in Gabaix (2012) to match the expected return on housing from our baseline calibration (6.5%). This requires modeling housing as a slightly safer claim than equity with respect to disasters with an average resilience of 0.1 instead of 0.09. We also modify the growth rate of dividends (rents) to match the 0.7% annual growth rate of rents, as in our baseline calibration.

increases ($T \to \infty$).

In the paper, therefore, we augmented the hyperbolic discount function to include an exponential term: $\frac{e^{-\rho s}}{1+\kappa s}$, where $\rho > 0$ is the subjective discount rate associated with exponential discounting. This form of discounting tends to behave like hyperbolic discounting in the short run and like exponential discounting in the long run. Since the long-run discount rate approaches ρ, finite prices for long-run securities in the presence of cash-flow growth g are guaranteed by $\rho > g$. The T-maturity leasehold is valued at:

$$P_0^T = \int_0^T \frac{e^{-(\rho-g)s}}{1+\kappa s} D_0 ds = D_0 \frac{e^{\frac{\rho-g}{\kappa}} \left(Ei\left(\frac{(T\kappa+1)(g-\rho)}{\kappa} \right) - Ei\left(\frac{g-\rho}{\kappa} \right) \right)}{\kappa},$$

where $Ei(x)$ is the Exponential Integral function defined as:

$$Ei(x) \equiv - \int_{-x}^{\infty} \frac{e^{-t}}{t} dt.$$

The freehold is correspondingly valued at:

$$P_0 = D_0 \frac{e^{\frac{\rho-g}{\kappa}} \Gamma\left(0, \frac{\rho-g}{\kappa}\right)}{\kappa},$$

where $\Gamma(x)$ is the Upper Incomplete Gamma Function defined as:[83]

$$\Gamma(0, x) \equiv \int_x^{\infty} \frac{e^{-t}}{t} dt.$$

The discount is now:

$$Disc_0^T = \frac{Ei\left(\frac{(T\kappa+1)(g-\rho)}{\kappa} \right) - Ei\left(\frac{g-\rho}{\kappa} \right)}{\Gamma\left(0, \frac{\rho-g}{\kappa}\right)} - 1.$$

The per-period equivalent constant discount rate r_T for horizon T solves $e^{-r_T T} = R_{0,T} = \frac{e^{-\rho T}}{1+\kappa T}$, and is hence obtained via the formula:

$$r_T = \rho + \frac{\ln(1+\kappa T)}{T}.$$

This is the formula reported in the main text. Notice that we also have $\lim_{T \downarrow 0} r_T = \rho + \kappa$

[83] Notice $\Gamma(0, x) = -Ei(-x)$.

and $\lim_{T\to\infty} r_T = \rho$.[84] So that total discount rates start at $\rho+\kappa$ and then decay over the horizon to ρ.

Similarly, marginal discount rates $r(s)$ can be derived by defining the discount function as $R_{0,T} = exp\left(-\int_0^T r(s)ds\right)$. Then an application of Leibniz's rule for differentiation under the integral sign yields: $\dot{R_{0,T}} = -r(T)R_{0,T}$, where $\dot{R_{0,T}}$ is the time derivative of function $R_{0,T}$. Hence, we have the result hat $r(T) = -\frac{\dot{R_{0,T}}}{R_{0,T}}$. Finally, applying this formula to the exponential-hyperbolic discount function, $R_{0,T} = \frac{e^{-\rho T}}{1+\kappa T}$, one obtains the result:

$$r(T) = -\frac{\dot{R_{0,T}}}{R_{0,T}} = \rho + \frac{\kappa}{1+\kappa t}.$$

Marginal discount rates are therefore monotonically decreasing from $\rho+\kappa$ to ρ. We conclude, therefore, that r_T are also monotonically decreasing.

We next derive the expected, instantaneous returns to the freehold. Before deriving the expression for the current hyperbolic-exponential model, we report the derivation for the simple Gordon growth exponential model. In the main draft we have argued that the constant discount rate r of the Gordon growth model should be calibrated to the average return of the freehold. We confirm here that this logic is correct. The return on the freehold is given by:

$$\frac{dP_t + D_t dt}{P_t}.$$

In the Gordon growth environment capital gains are $\frac{dP_t}{P_t} = gdt$. This can be derived recalling that $P_t = \frac{D_t}{r-g} = \frac{D_0 e^{gt}}{r-g}$ and taking the time derivative. The rental yield is $\frac{D_t}{P_t} = r-g$. We conclude that total returns on the freehold in the Gordon growth model are:

$$\frac{dP_t + D_t dt}{P_t} = gdt + (r-g)dt = rdt.$$

We now derive the formula for expected returns to the freehold in our hyperbolic-exponential model by analogy with the Gordon growth model derivation above. The capital gains in our hyperbolic-exponential model are $\frac{dP_t}{P_t} = gdt$. This can be derived by recalling that $P_t = D_t \frac{e^{\frac{\rho-g}{\kappa}}\Gamma\left(0,\frac{\rho-g}{\kappa}\right)}{\kappa} = D_0 e^{gt} \frac{e^{\frac{\rho-g}{\kappa}}\Gamma\left(0,\frac{\rho-g}{\kappa}\right)}{\kappa}$, and taking the time derivative. The rental yield is $\frac{D_t}{P_t} = \frac{\kappa}{e^{\frac{\rho-g}{\kappa}}\Gamma\left(0,\frac{\rho-g}{\kappa}\right)}$. We conclude that total returns on the freehold in the hyperbolic-

[84] The first limit follows from an application of l'Hopital's rule.

exponential model are:

$$\frac{dP_t + D_t dt}{P_t} = g dt + \frac{\kappa}{e^{\frac{\rho-g}{\kappa}} \Gamma\left(0, \frac{\rho-g}{\kappa}\right)} dt.$$

If $\kappa = 0$ then the return to the freehold is simply ρ, and we are back to the exponential discounting model. An increase in κ for a given ρ has the following comparative statics: the returns to the freehold increase, short term discount rates increase, long-term discount rates are unchanged, and leasehold discounts $(Disc)$ increase in absolute value. These dynamics are precisely what allow the reduced-form hyperbolic-exponential model to reconcile the long-run valuation pattern.

A.4.4 Details on Financing Frictions

We assume that for the last $\bar{T}$ years of lease maturity the house has lower collateral value. We model this has an effective rent for the last $\bar{T}$ years that is a fraction $(1-\alpha)$ of the original rent. The value of the lease now follows:

$$\begin{aligned}
P_t^T &= \int_t^{t+T} e^{-\rho(s-t)} D_t e^{g(s-t)} (1 - \alpha \mathbf{1}_{\{s>t+T-\bar{T}\}}) ds \qquad \text{(A.5)} \\
&= \int_t^{t+T} e^{-\rho(s-t)} D_t e^{g(s-t)} ds - \alpha \int_{t+T-\bar{T}}^{t+T} e^{-\rho(s-t)} D_t e^{g(s-t)} ds + \\
&\quad \mathbf{1}_{\{T<\bar{T}\}}\, \alpha \int_{t+T-\bar{T}}^{t} e^{-\rho(s-t)} D_t e^{g(s-t)} ds \\
&= \frac{D_t}{\rho - g} \left[1 - e^{-(\rho-g)T} - \alpha\left(e^{-(\rho-g)(T-\bar{T})} - e^{-(\rho-g)T}\right) + \mathbf{1}_{\{T<\bar{T}\}}\, \alpha \left(e^{-(\rho-g)(T-\bar{T})} - 1\right)\right]
\end{aligned}$$

Notice that the first multiplicative term in equation (A.5) is simply the valuation of the freehold under the Gordon-Growth formula $\left(\frac{D_t}{\rho-g}\right)$. The first term inside the squared bracket $\left(1 - e^{-(\rho-g)T}\right)$ is the Gordon-Growth price adjustment for the value of a T-maturity leasehold as shown in equation (4). The second term inside the squared bracket is the loss in value for the T-maturity leasehold due to the frictions. Notice that this term is zero whenever there are no frictions ($\alpha = 0$ and or $\bar{T} = 0$). The last term inside the squared bracket $\left(\mathbf{1}_{\{T<\bar{T}\}}\, \alpha \left(e^{-(\rho-g)(T-\bar{T})} - 1\right)\right)$ captures the notion that if a leasehold has already less than $\bar{T}$ years left than it would be valued at:

$$P_t^T = \frac{D_t(1-\alpha)}{\rho - g}(1 - e^{-(\rho-g)T}),$$

so that the leasehold is then valued as if the rents where only a fraction$(1-\alpha)$ of the original ones. Notice that the value of the freehold is unaffected by the frictions because by definition it never loses its collateral value:

$$P_t = \lim_{T\to\infty} P_t^T = \frac{D_t}{\rho - g}.$$

The model implied discounts are now:

$$Disc_t^T = e^{-(\rho-g)T} + \alpha\left(e^{-(\rho-g)(T-\bar{T})} - e^{-(\rho-g)T}\right) - \mathbf{1}_{\{T<\bar{T}\}}\,\alpha\left(e^{-(\rho-g)(T-\bar{T})} - 1\right).$$

Let us focus on the case in which $T > \bar{T}$, i.e. if we are valuing a leasehold with maturity beyond the problematic threshold. Notice the following effects:

1. $\frac{\partial Disc_t^T}{\partial \alpha} > 0$, the discount increases the greater the per-period collateral benefit.
2. $\frac{\partial Disc_t^T}{\partial \bar{T}} > 0$, the discount increases whenever the threshold for financing increases.
3. $\frac{\partial Disc_t^T}{\partial \alpha \partial T} < 0$ and $\lim_{T\to\infty} \frac{\partial Disc_t^T}{\partial \alpha} = 0$, the marginal effect of the loss in collateral value on the discount decreases with maturity of the lease and is zero in the limit of very long leases.

The last property is the most relevant for our robustness exercise. It states that no matter how high the frictions are ($\uparrow \alpha$), their effect decreases with the length of the lease. As we have described in the main body of the paper, and reported in Figure A.39, this effect makes the frictions quantitatively incapable of explaining the observed discounts, especially for long term leases (100 or 200 years for example).

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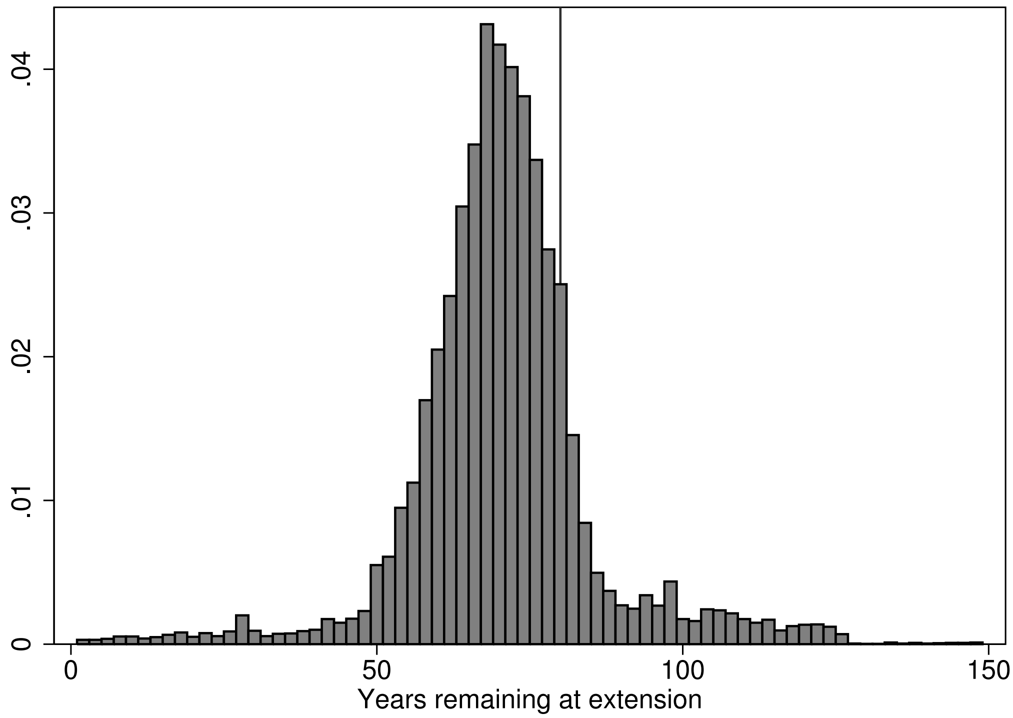
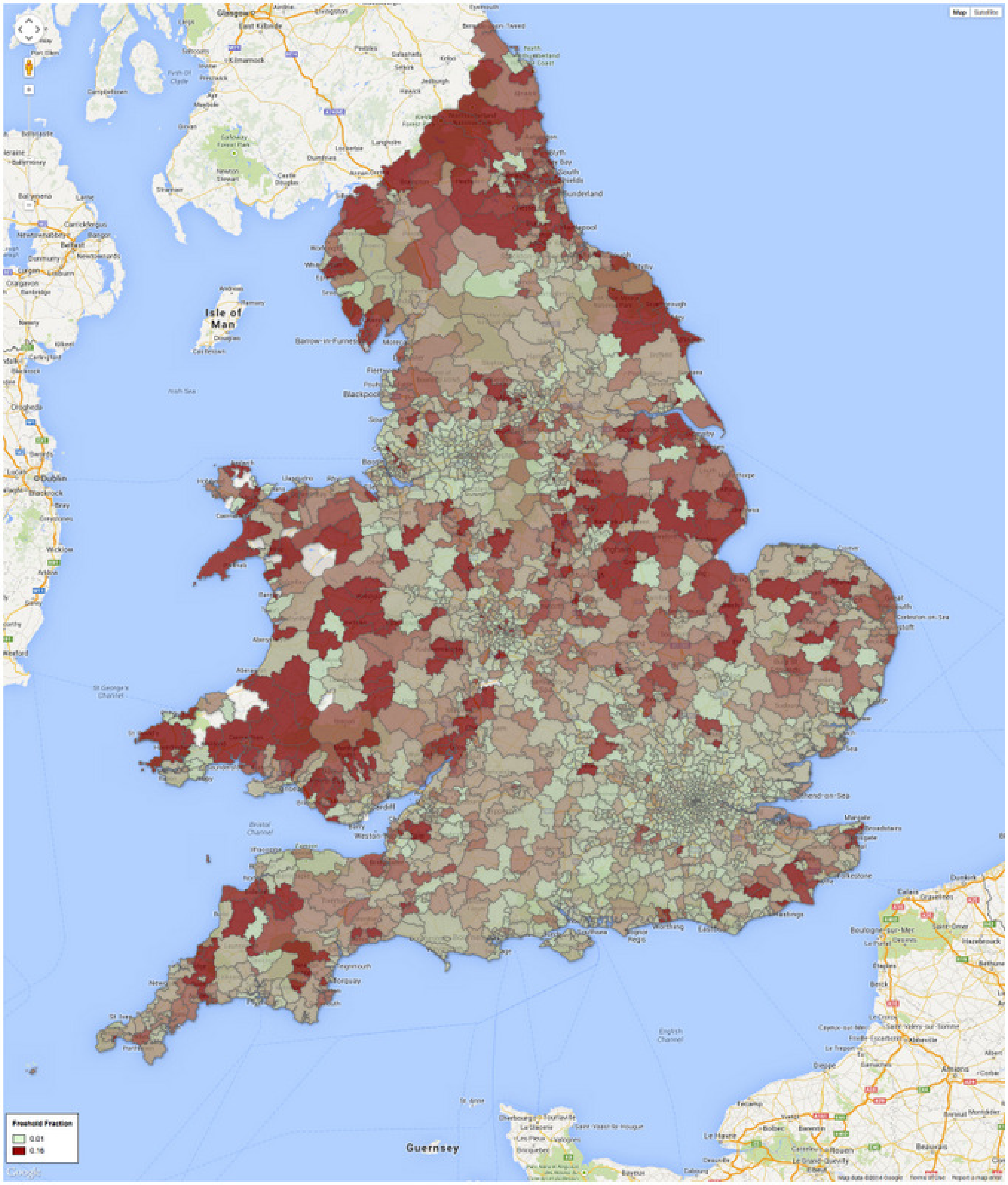
Appendix Figures

Figure A.1: Distribution of years remaining at lease extension



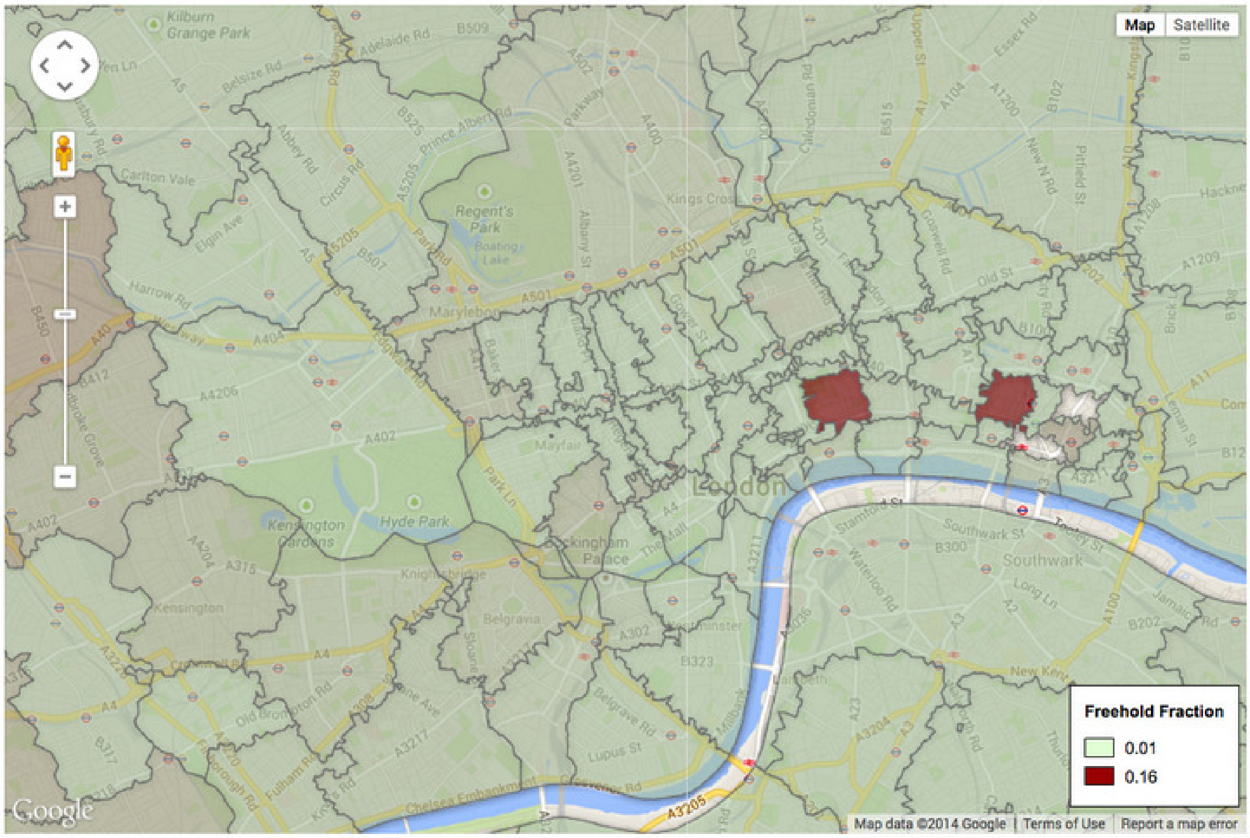
Note: The figure shows the distribution of the number of years remaining at the time of a lease extension for the subsample of 21,974 properties for which we can identify the time of the extension. The extensions are identified by finding all cases in which the same property transacts at least twice, in which different contracts appear across the various transactions. The years remaining at extension are the number of years remaining on the oldest contract as of the starting date of the next contract. The vertical bar corresponds to 80 years remaining.

Figure A.2: U.K. Flats: Fraction of Freeholds



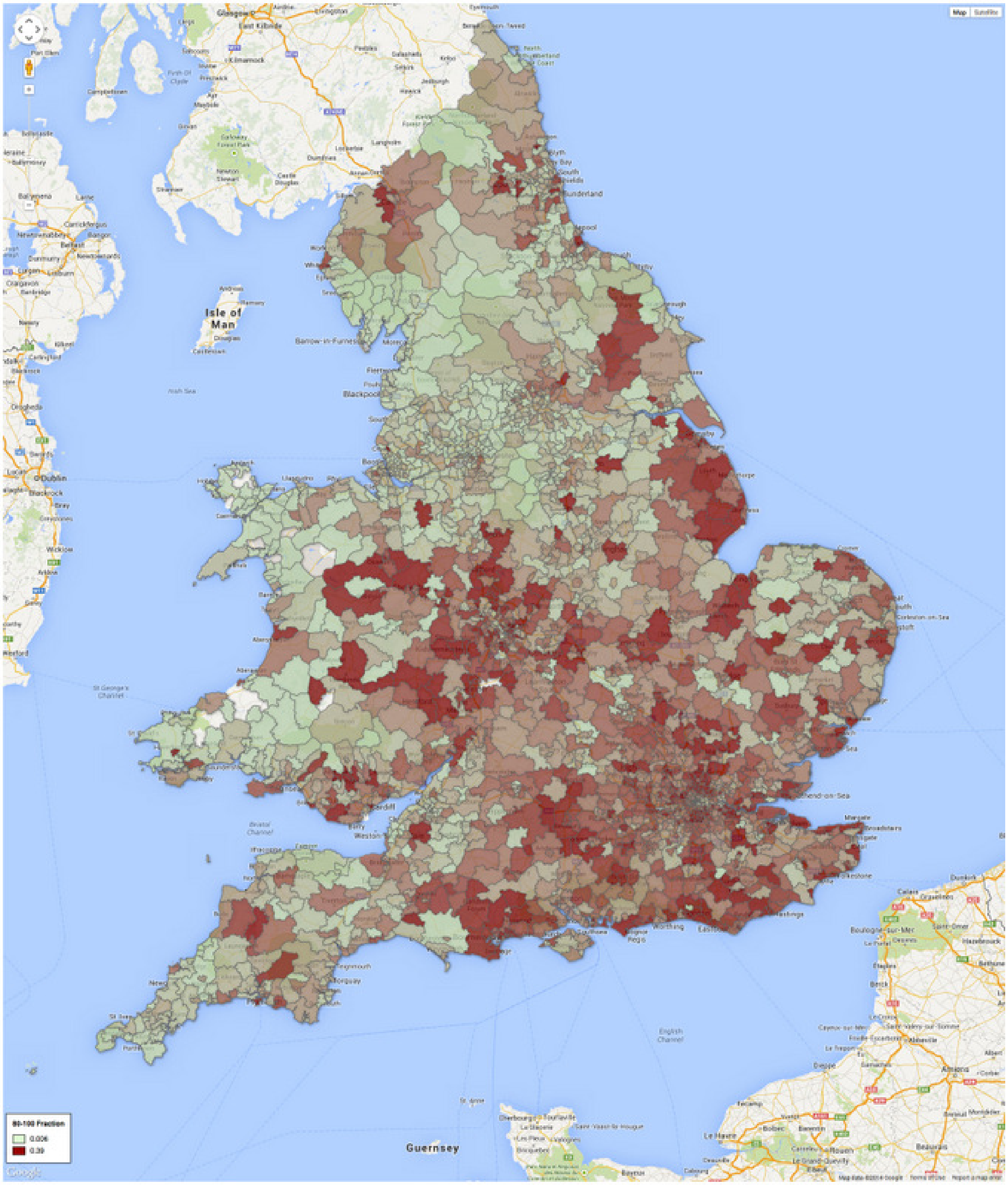
Note: The figure shows the fraction of freehold flats in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.3: London Flats: Fraction of Freeholds



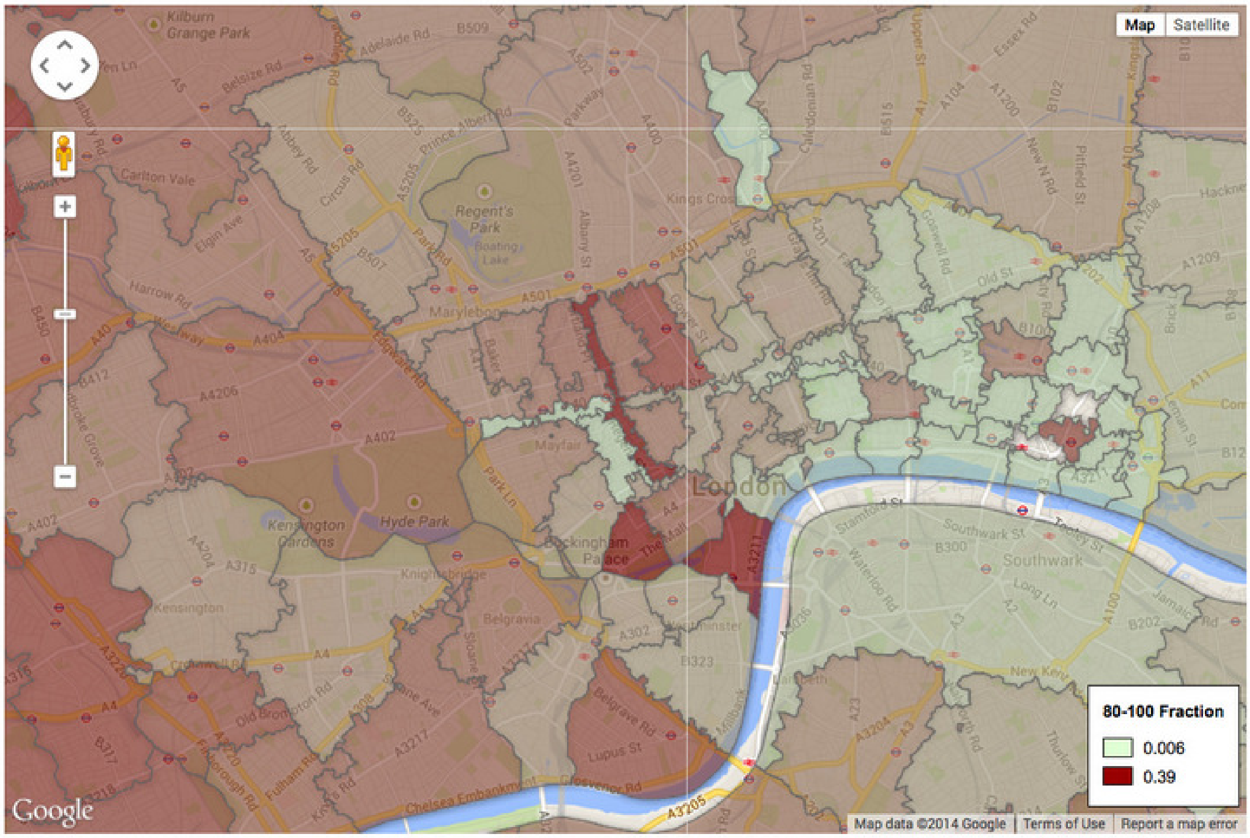
Note: The figure shows the fraction of freehold flats in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.4: U.K. Flats: Fraction of 80-99 years leaseholds



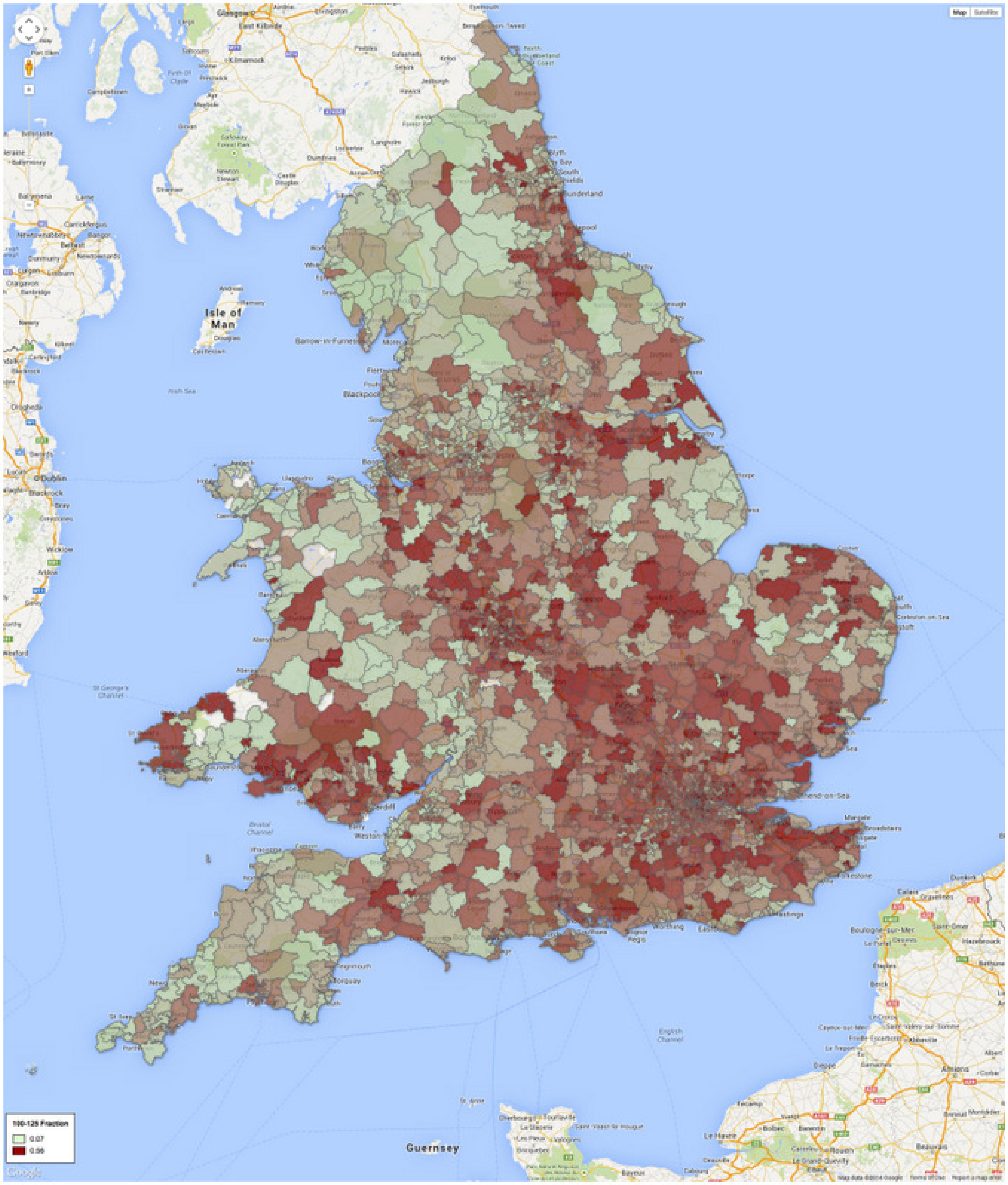
Note: The figure shows the fraction of flat transactions with 80-99 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.5: London Flats: Fraction of 80-99 years leaseholds



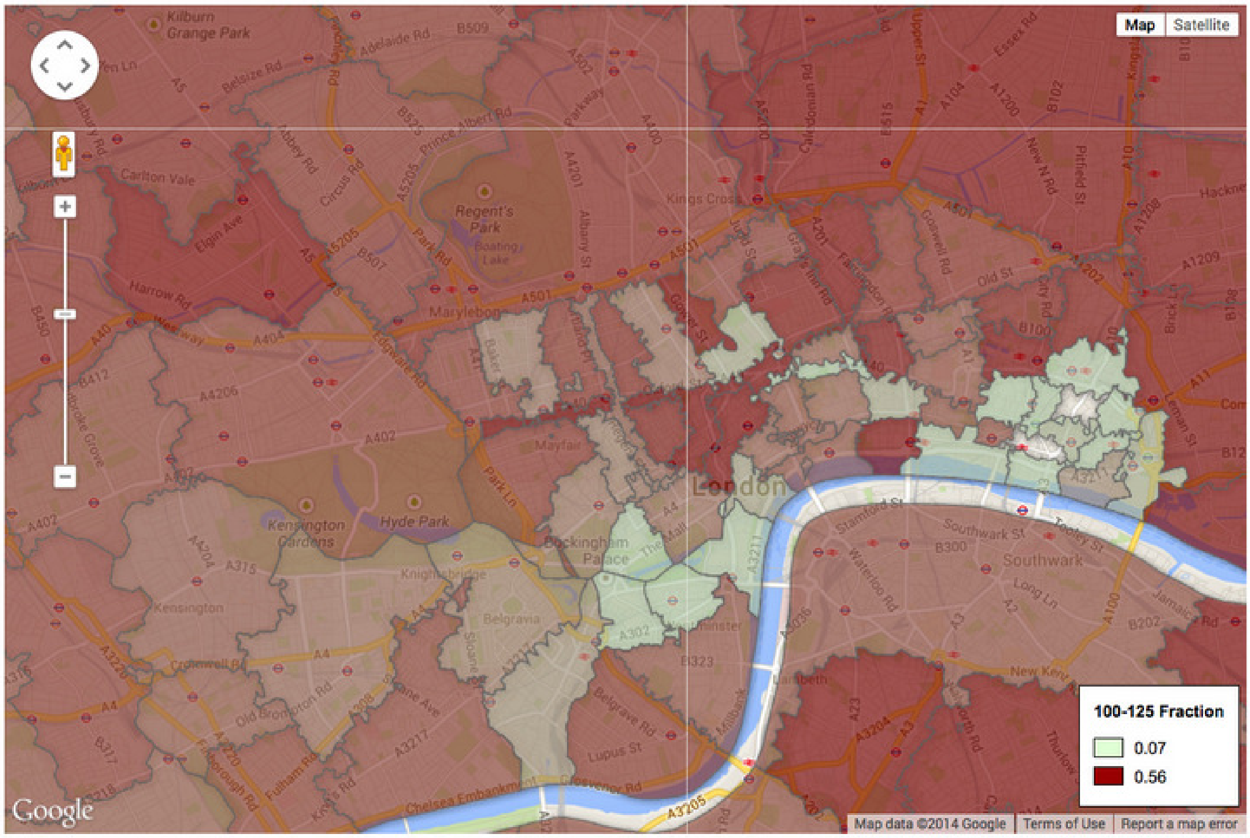
Note: The figure shows the fraction of flat transactions with 80-99 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.6: U.K. Flats: Fraction of 100-124 years leaseholds



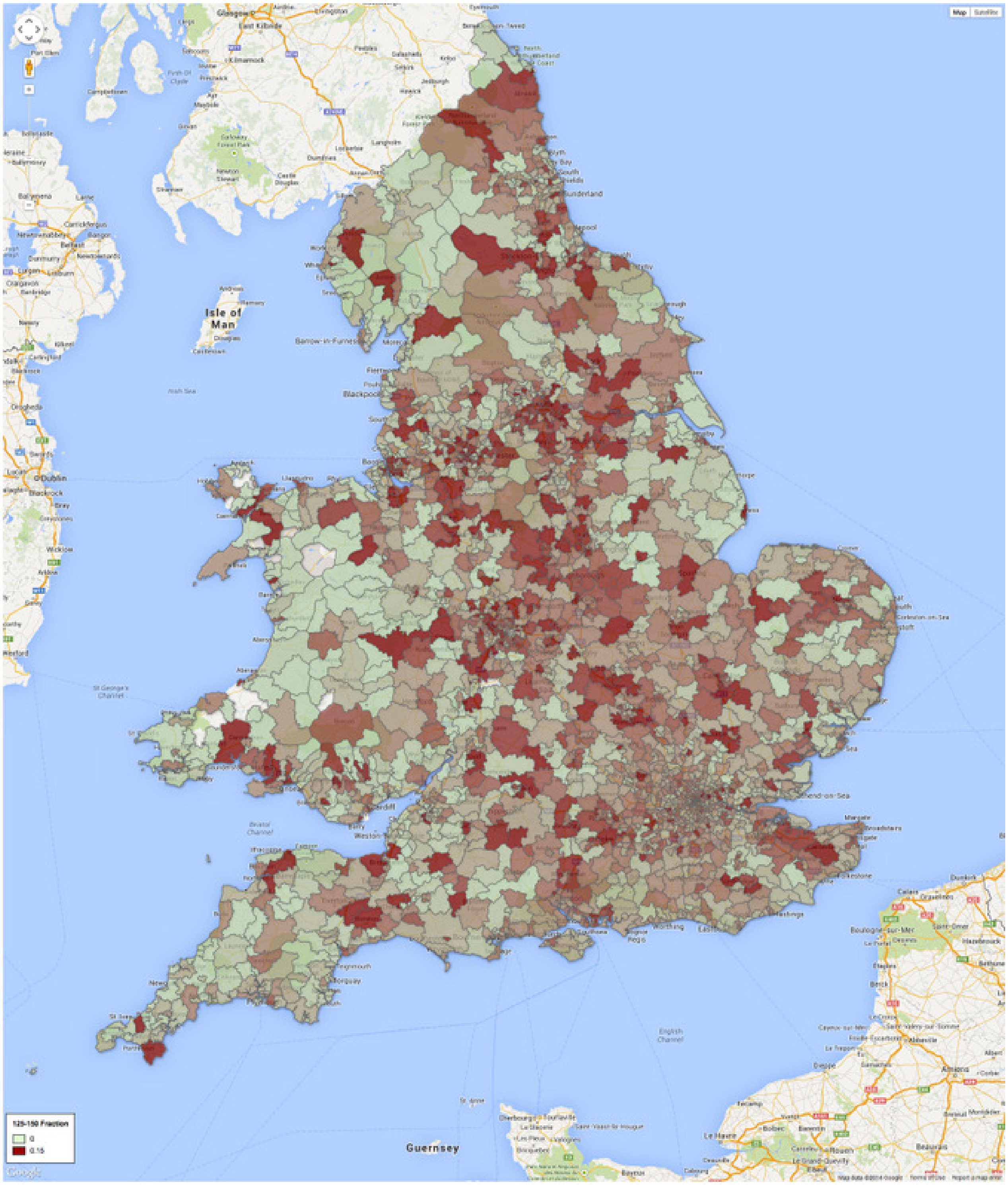
Note: The figure shows the fraction of flat transactions with 100-124 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.7: London Flats: Fraction of 100-124 years leaseholds



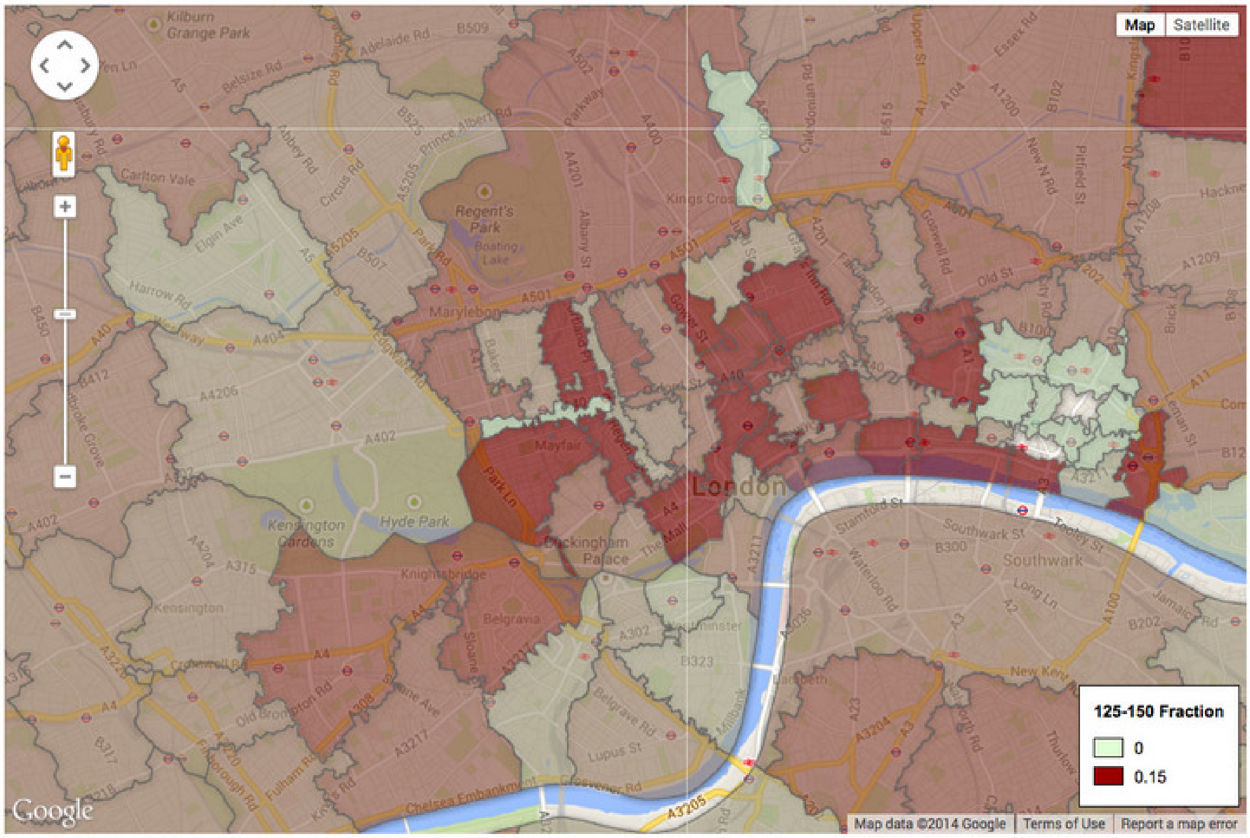
Note: The figure shows the fraction of flat transactions with 100-124 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.8: U.K. Flats: Fraction of 125-149 years leaseholds



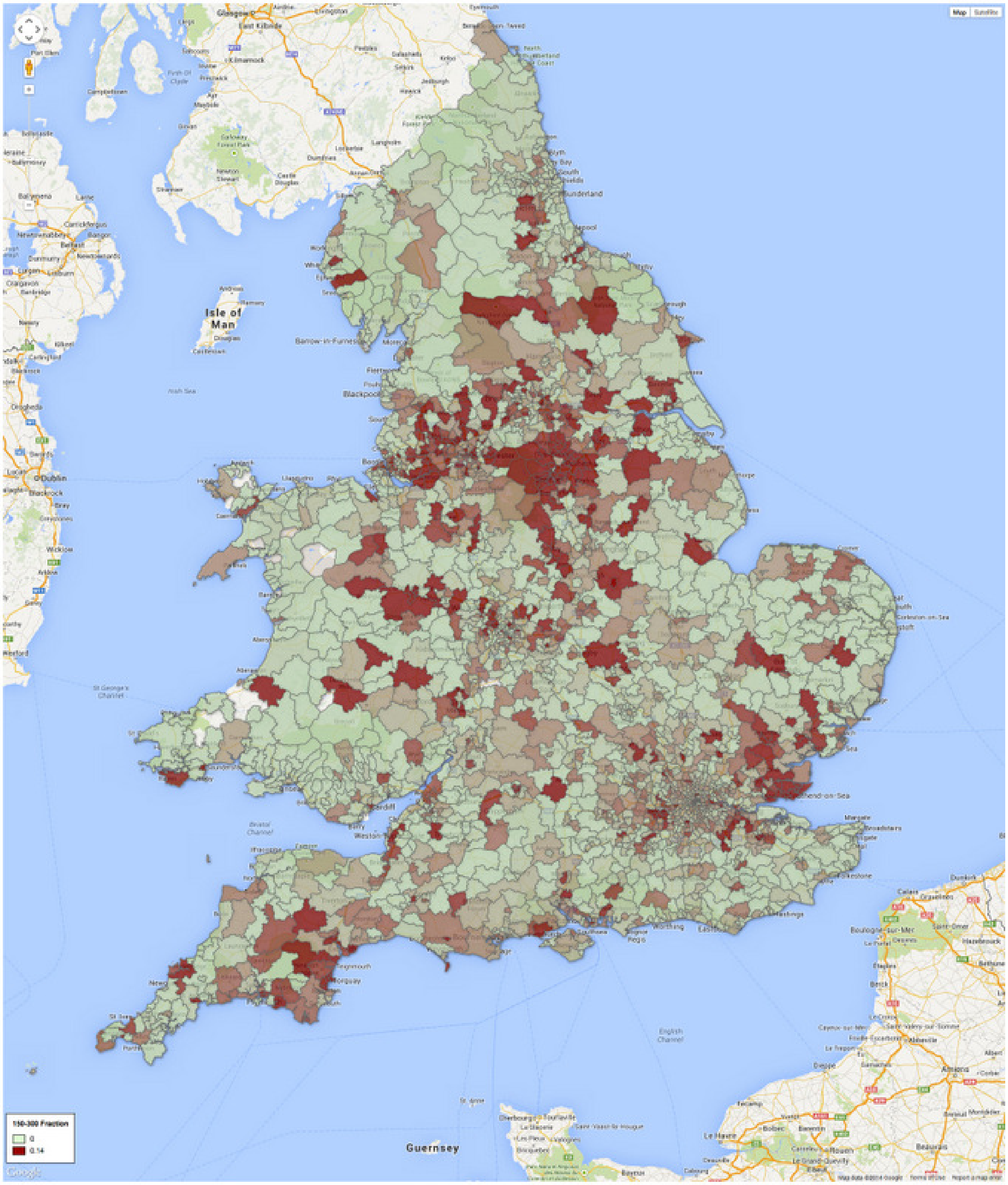
Note: The figure shows the fraction of flat transactions with 125-149 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.9: London Flats: Fraction of 125-149 years leaseholds



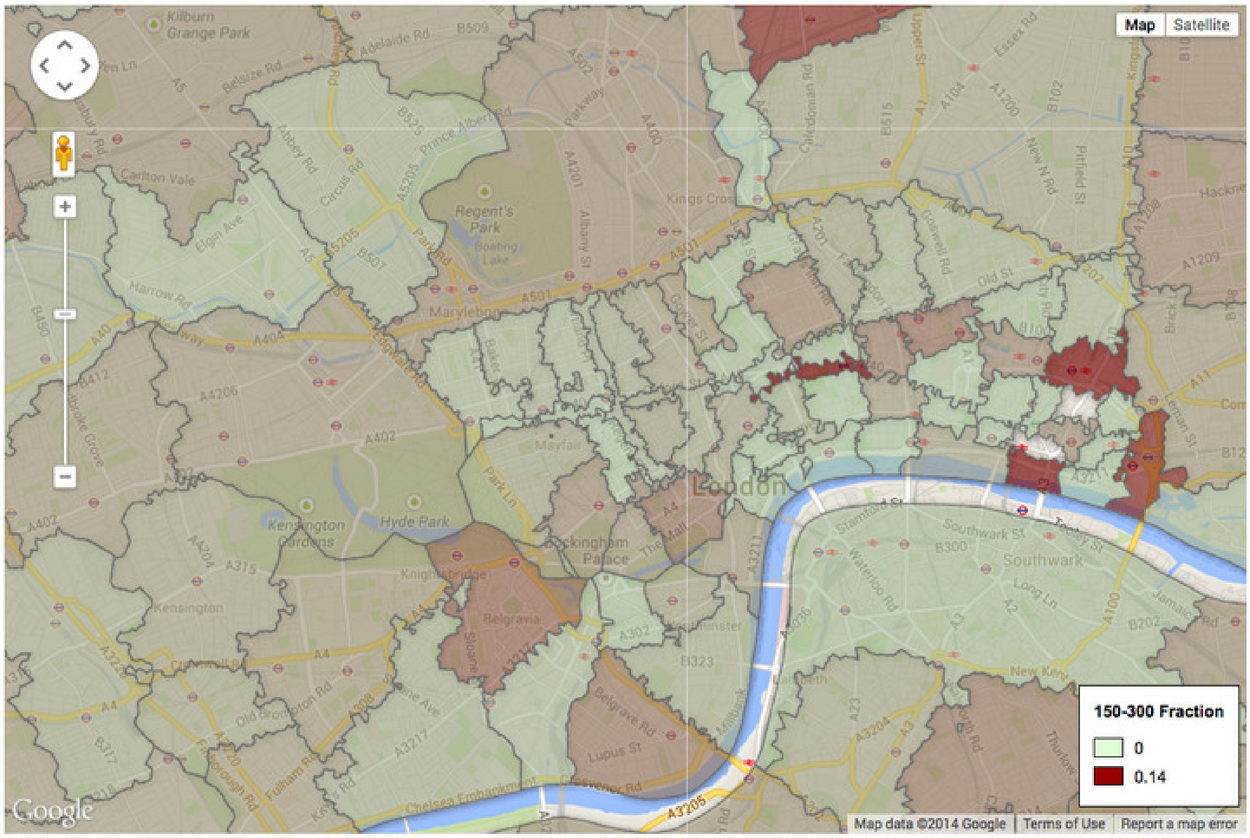
Note: The figure shows the fraction of flat transactions with 125-149 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.10: U.K. Flats: Fraction of 150-300 years leaseholds



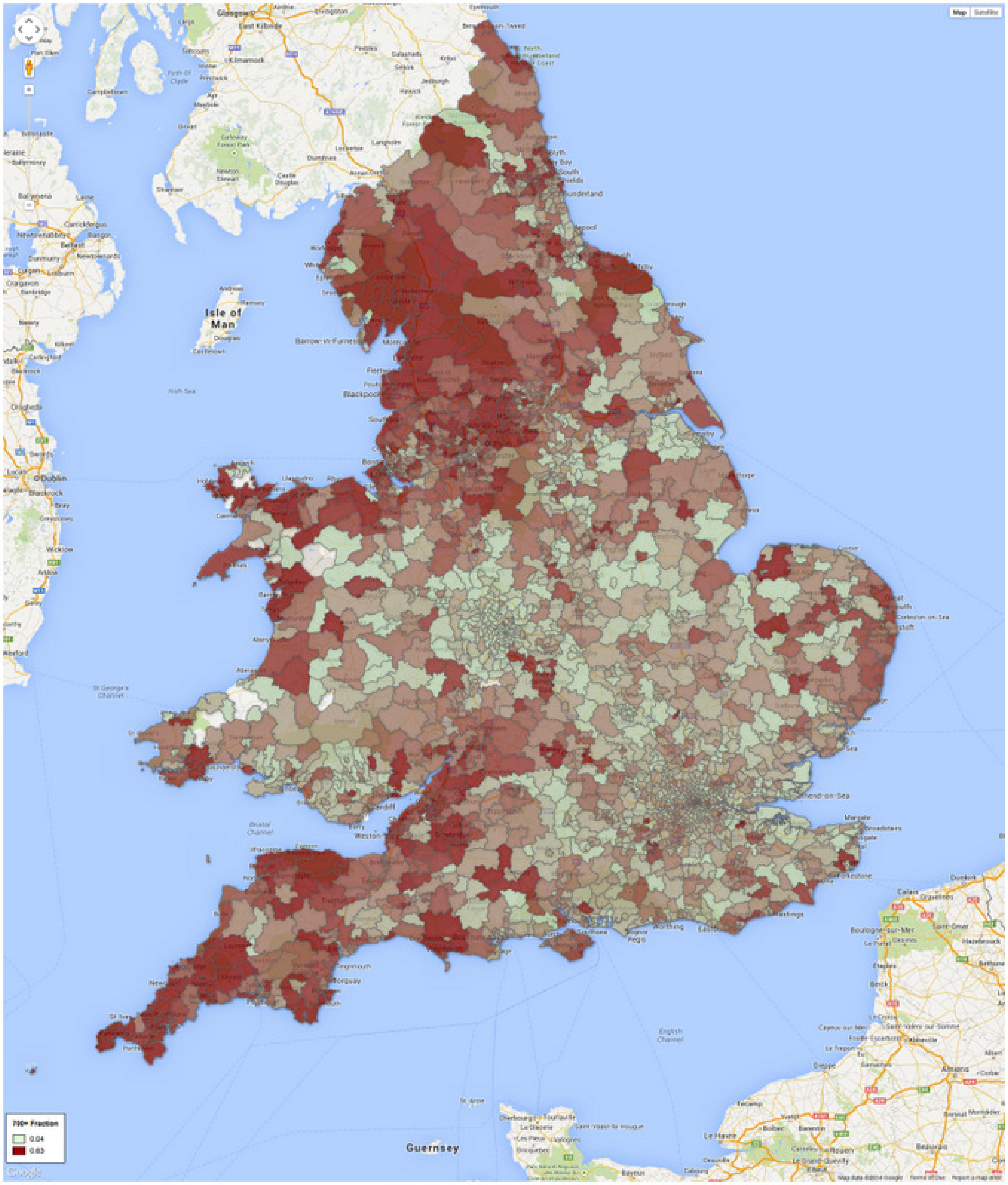
Note: The figure shows the fraction of flat transactions with 150-300 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.11: London Flats: Fraction of 150-300 years leaseholds



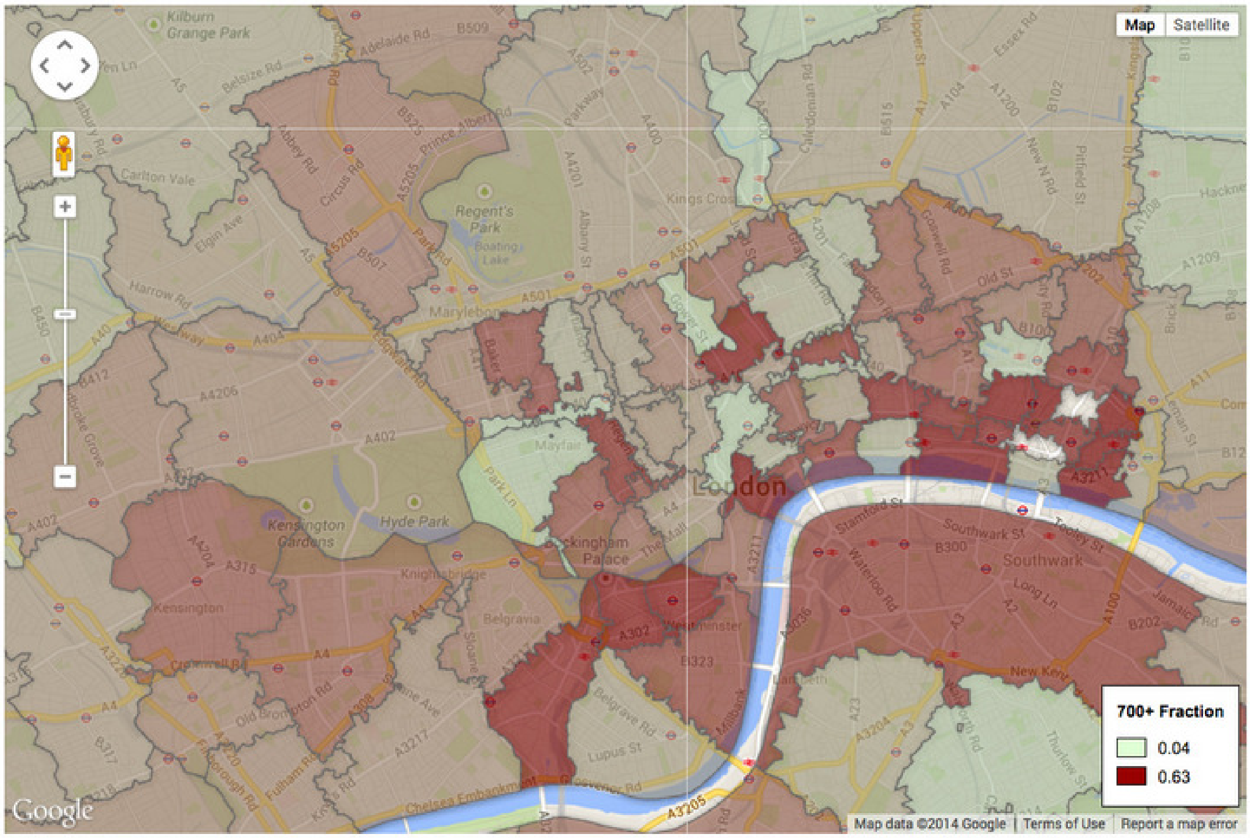
Note: The figure shows the fraction of flat transactions with 150-300 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.12: U.K. Flats: Fraction of 700+ years leaseholds



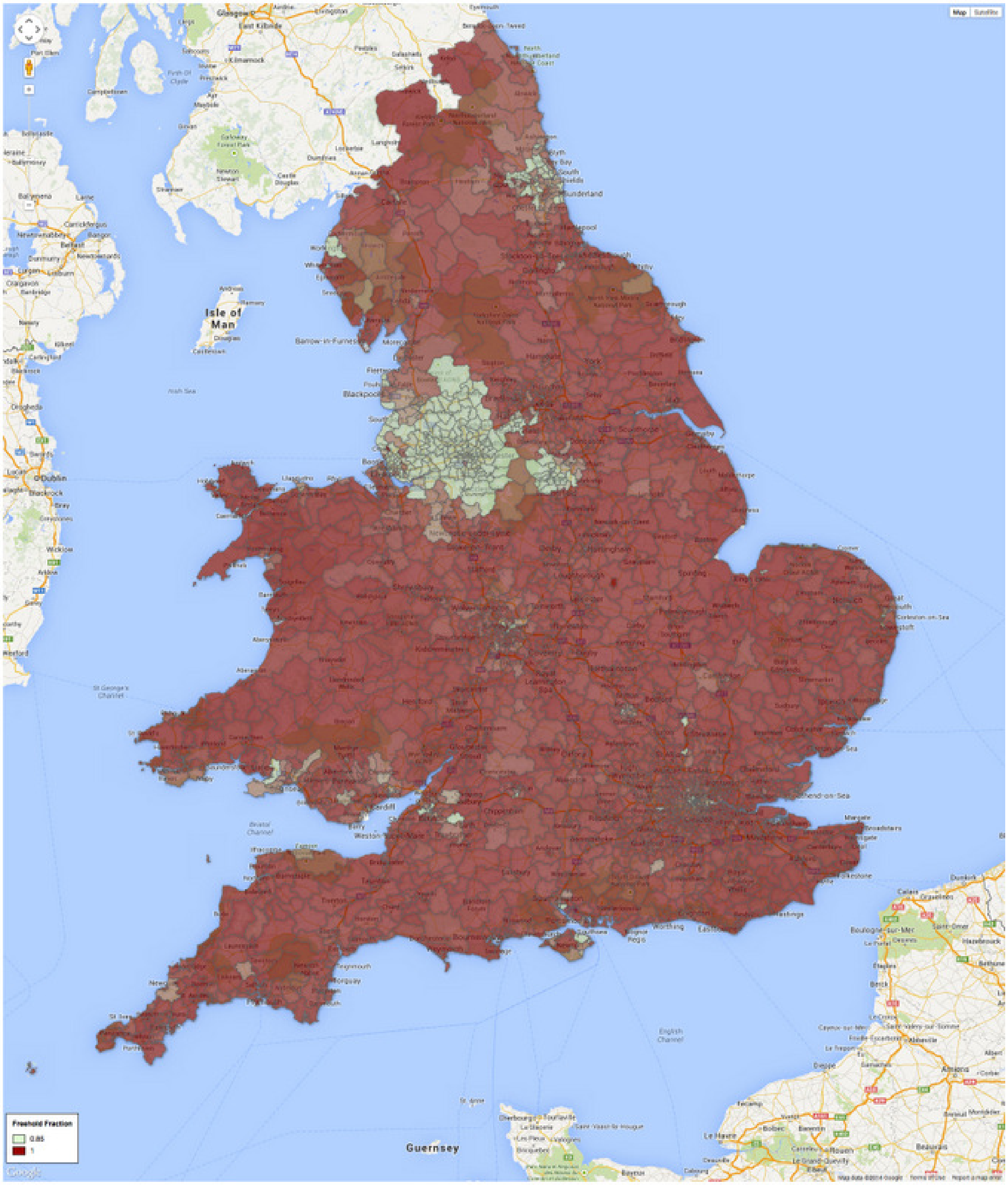
Note: The figure shows the fraction of flat transactions with 700+ years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.13: London Flats: Fraction of 700+ years leaseholds



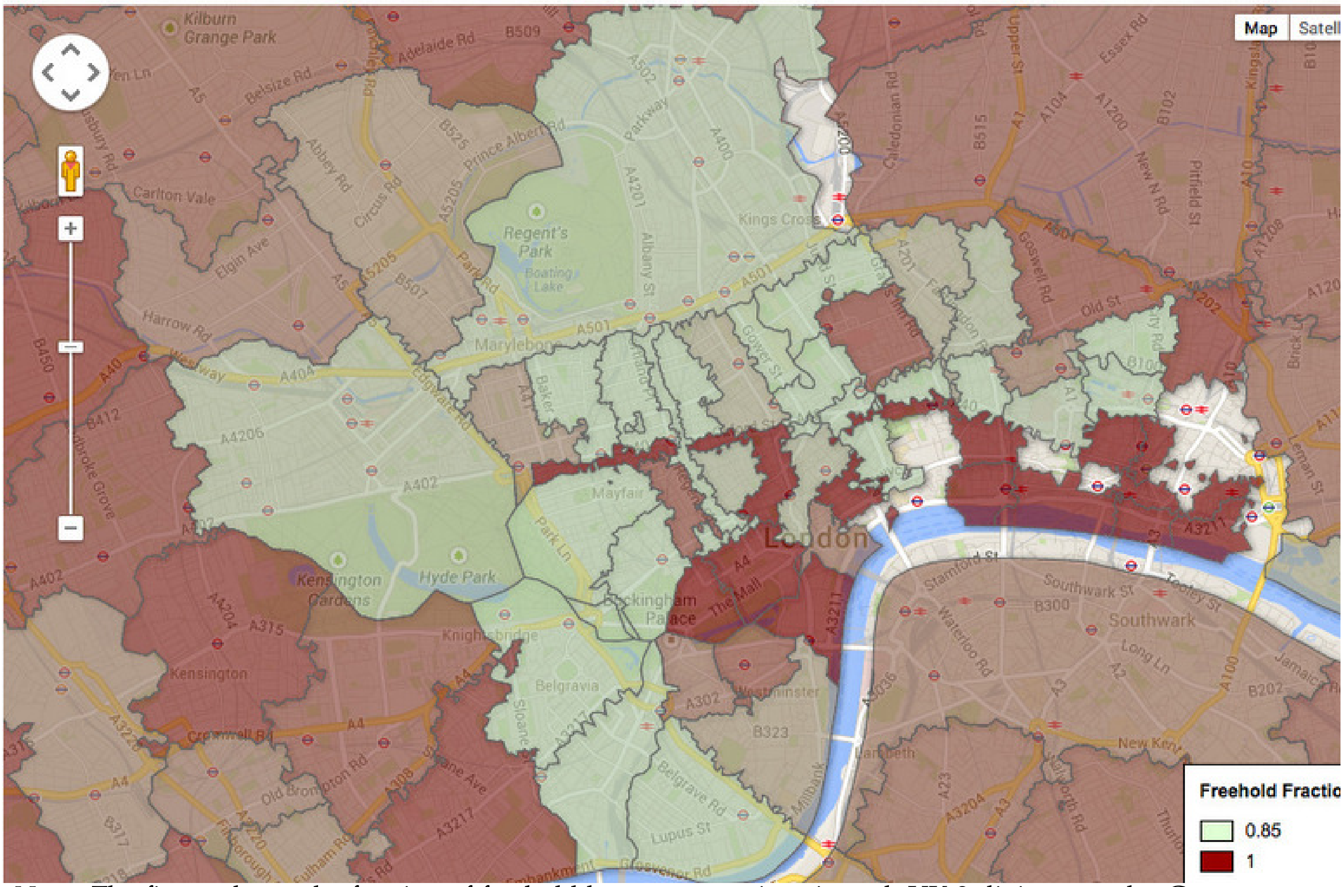
Note: The figure shows the fraction of flat transactions with 700+ years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.14: U.K. Houses: Fraction of Freeholds



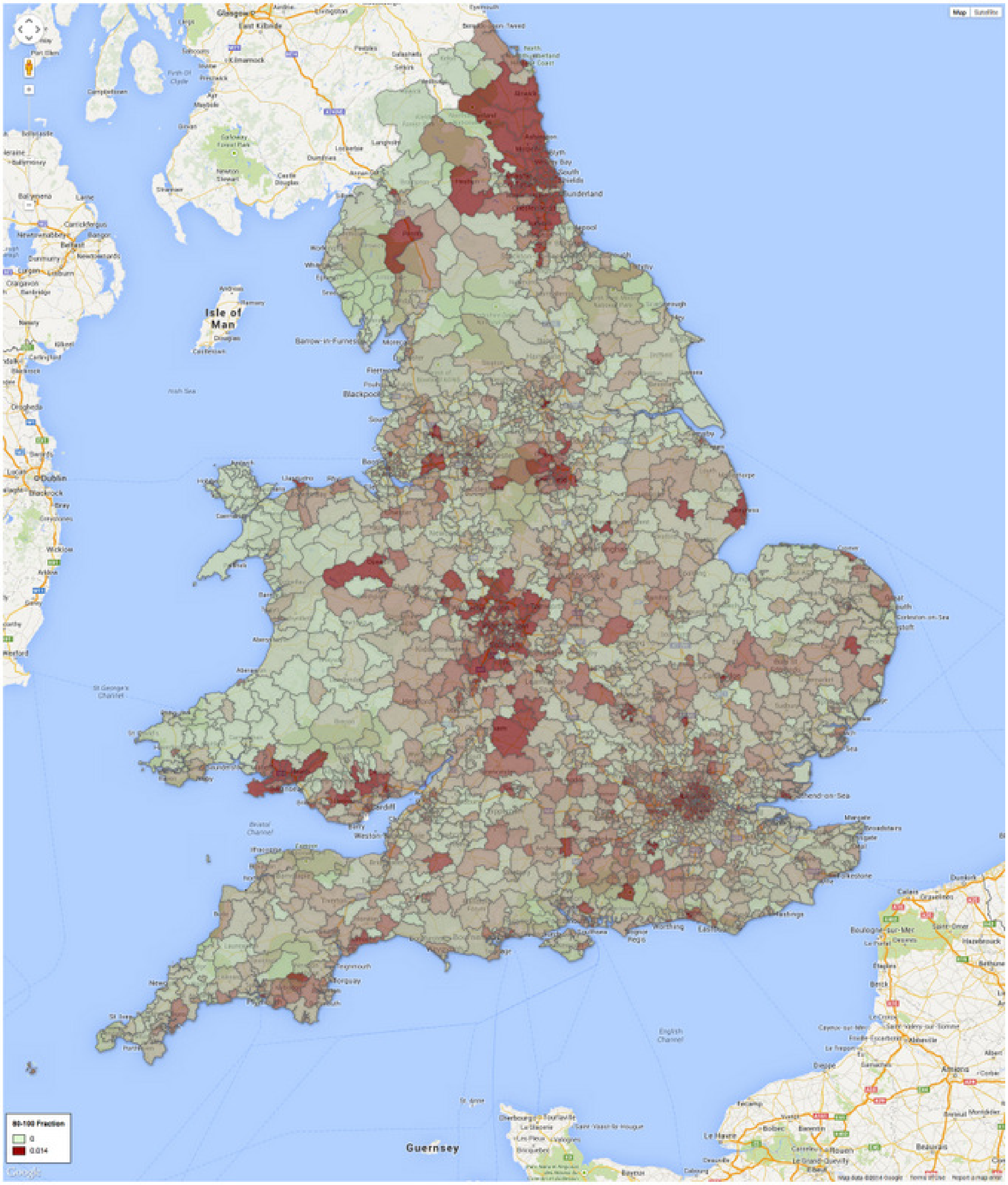
Note: The figure shows the fraction of freehold house transactions in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.15: London Houses: Fraction of Freeholds



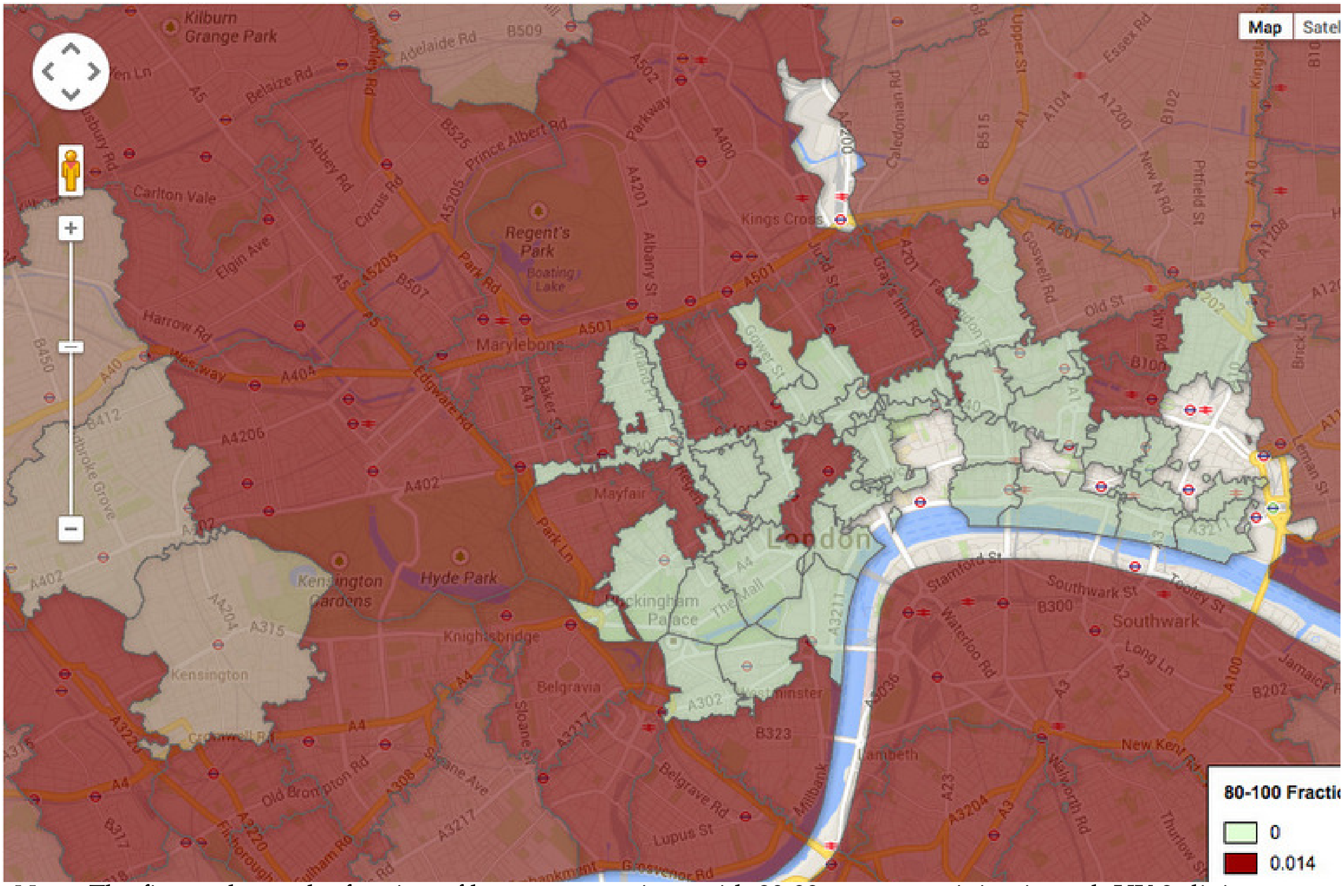
Note: The figure shows the fraction of freehold house transactions in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.16: U.K. Houses: Fraction of 80-99 years leaseholds



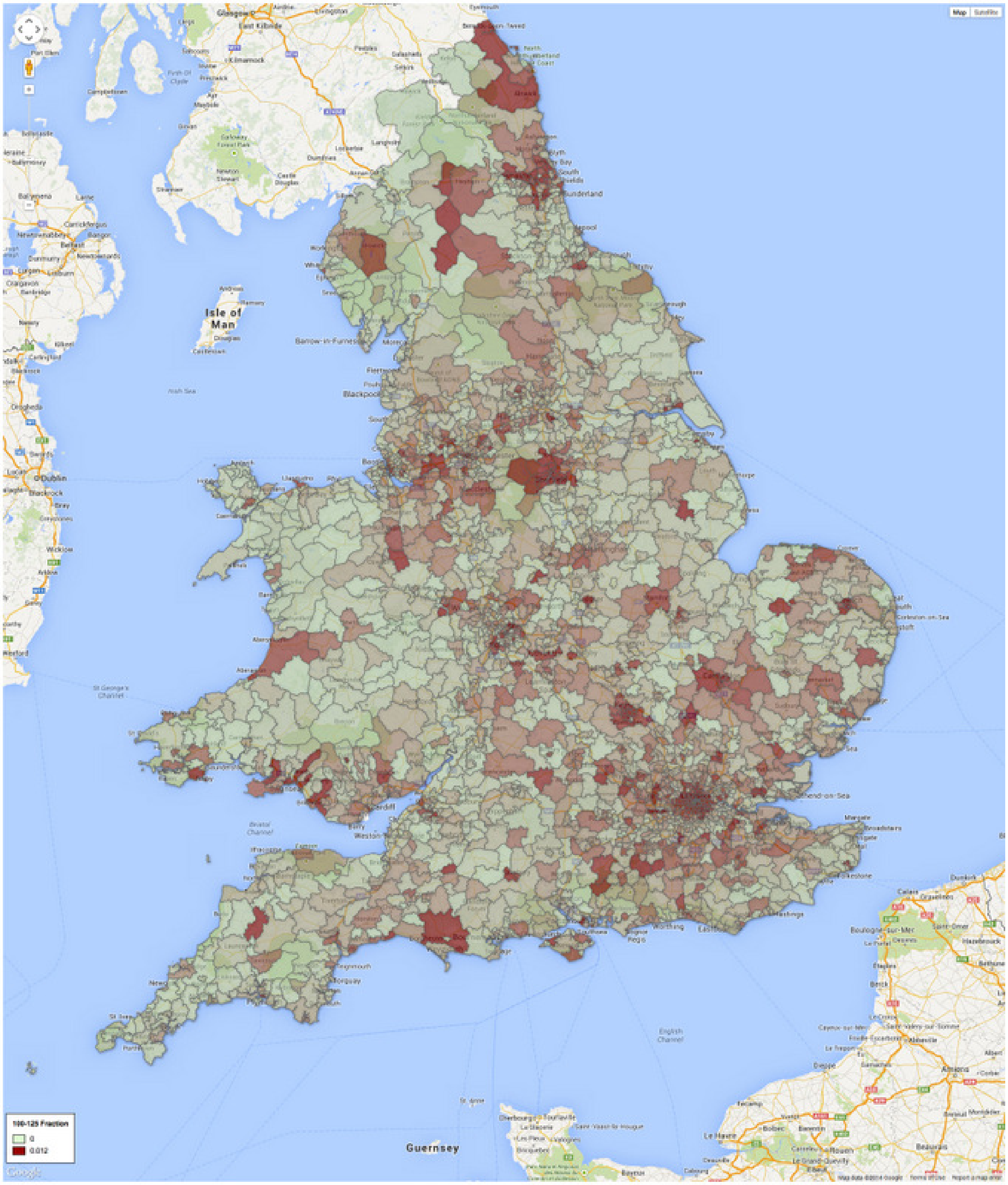
Note: The figure shows the fraction of house transactions with 80-99 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.17: London Houses: Fraction of 80-99 years leaseholds



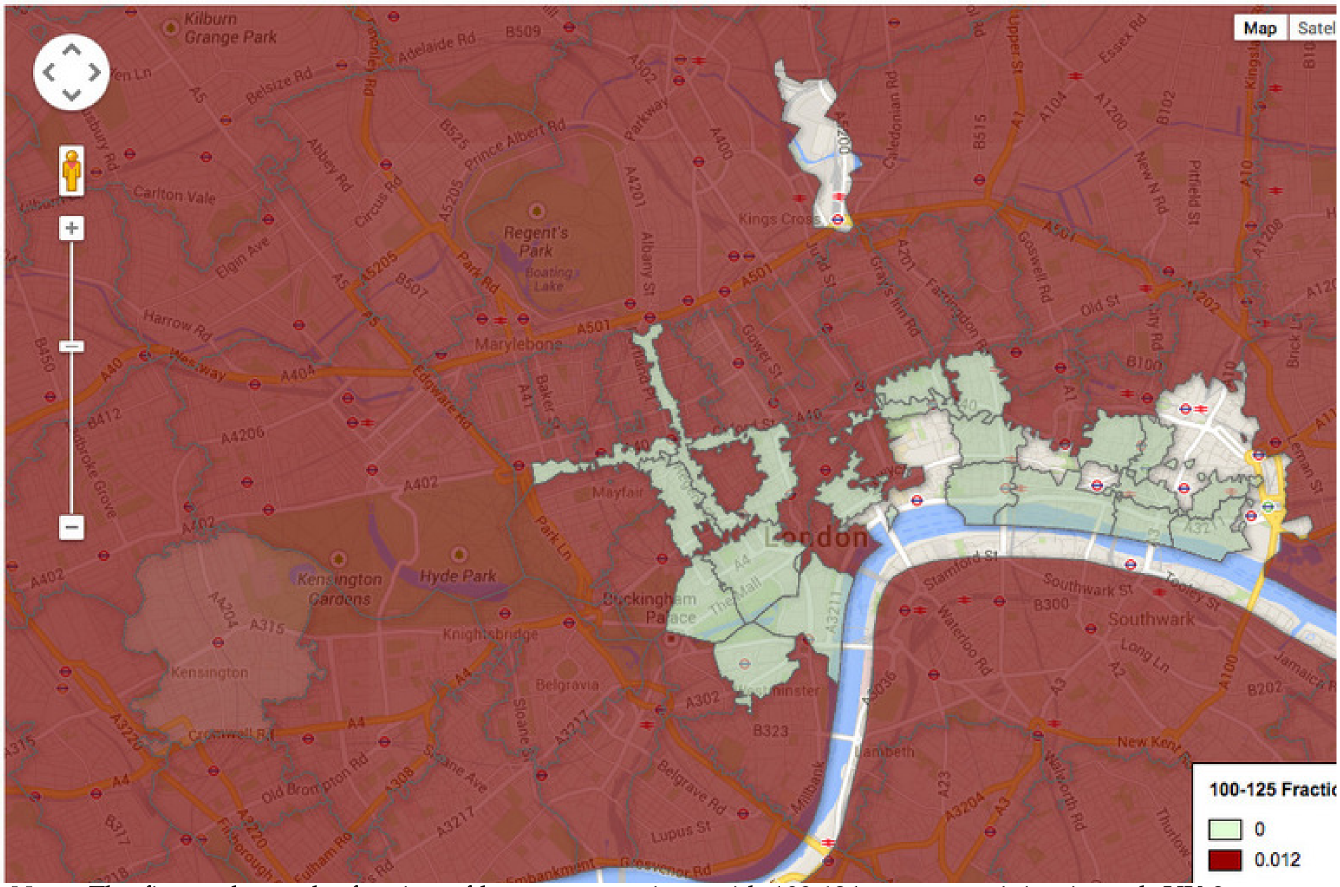
Note: The figure shows the fraction of house transactions with 80-99 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.18: U.K. Houses: Fraction of 100-124 years leaseholds



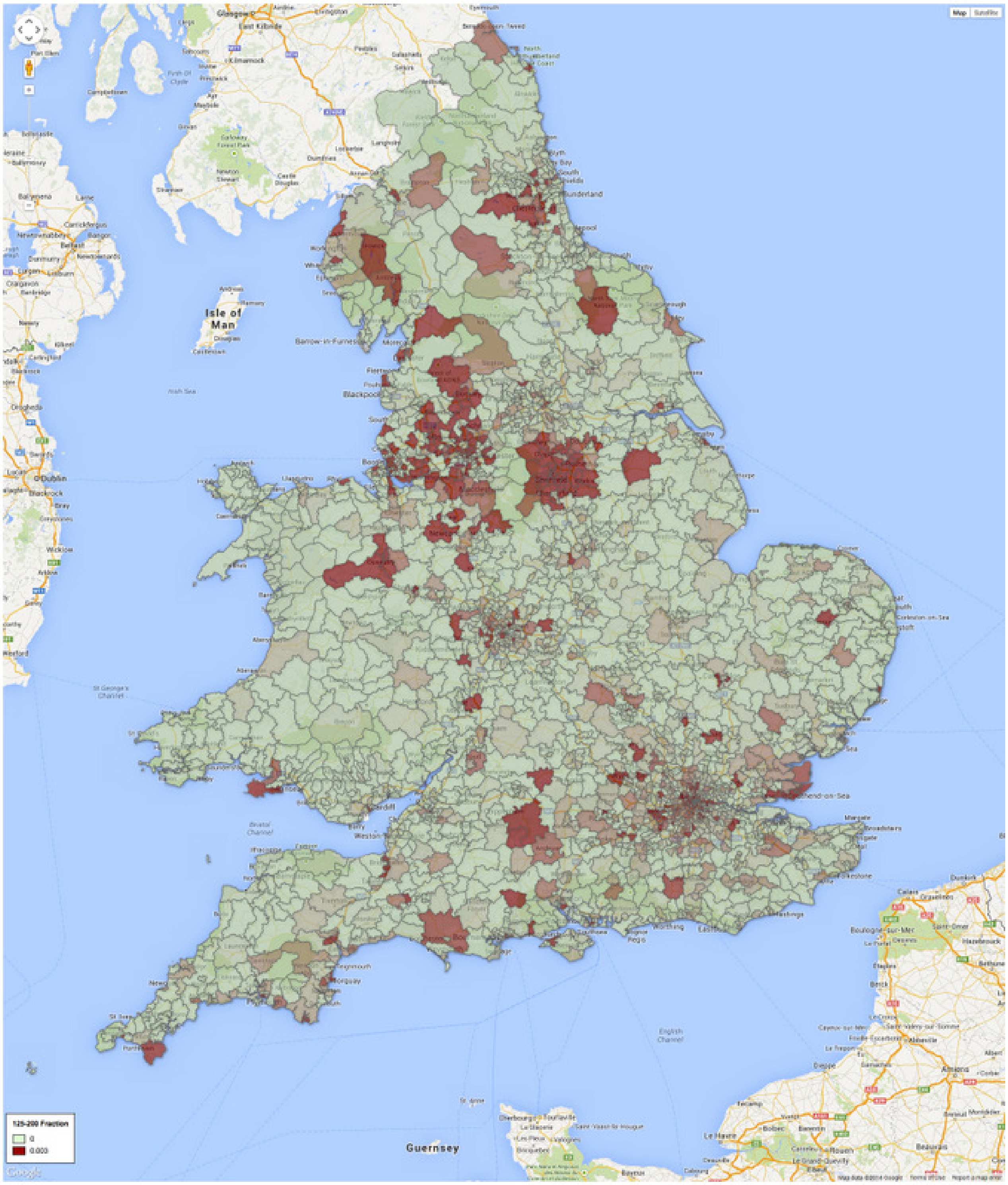
Note: The figure shows the fraction of house transactions with 100-124 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.19: London Houses: Fraction of 100-124 years leaseholds



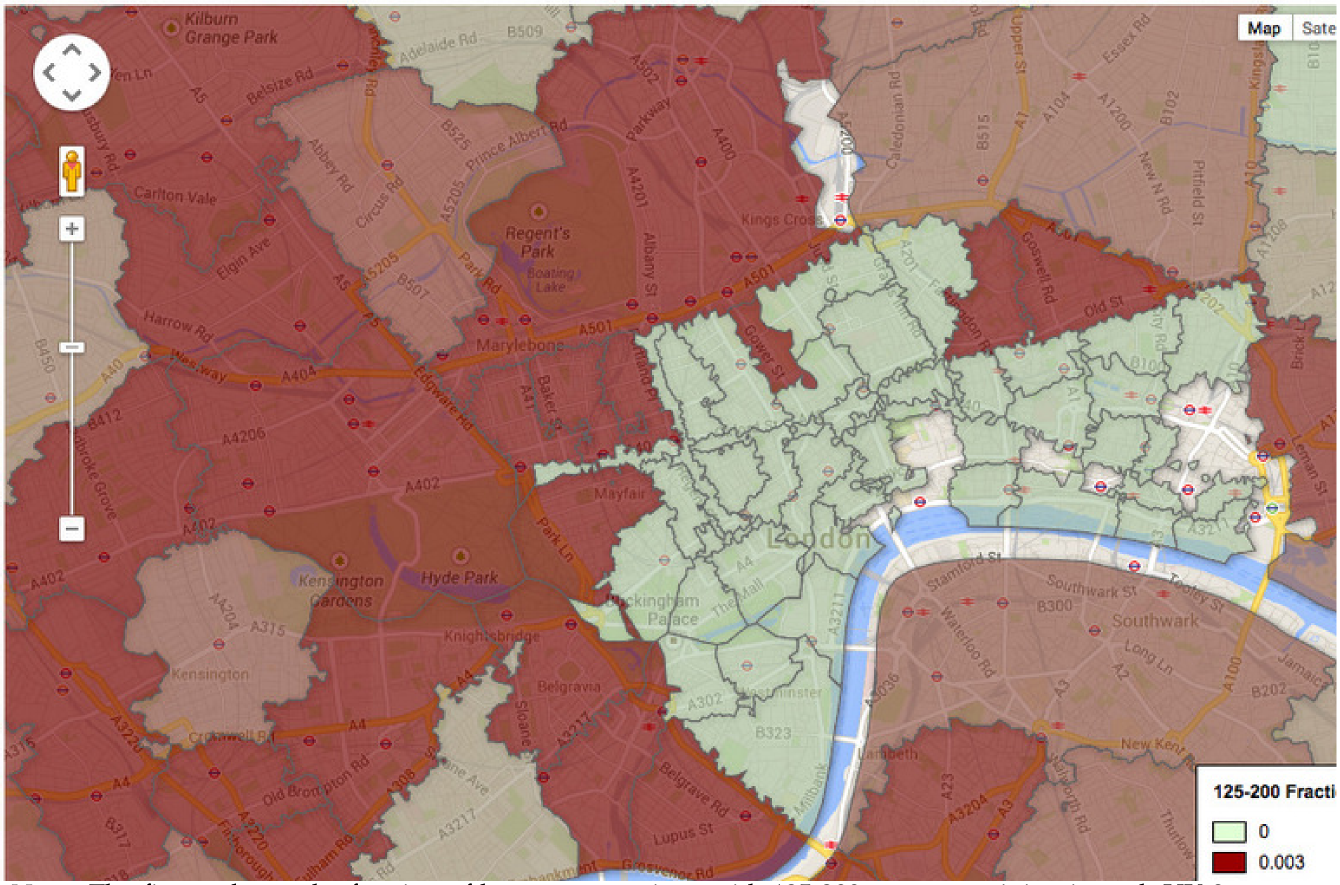
Note: The figure shows the fraction of house transactions with 100-124 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.20: U.K. Houses: Fraction of 125-200 years leaseholds



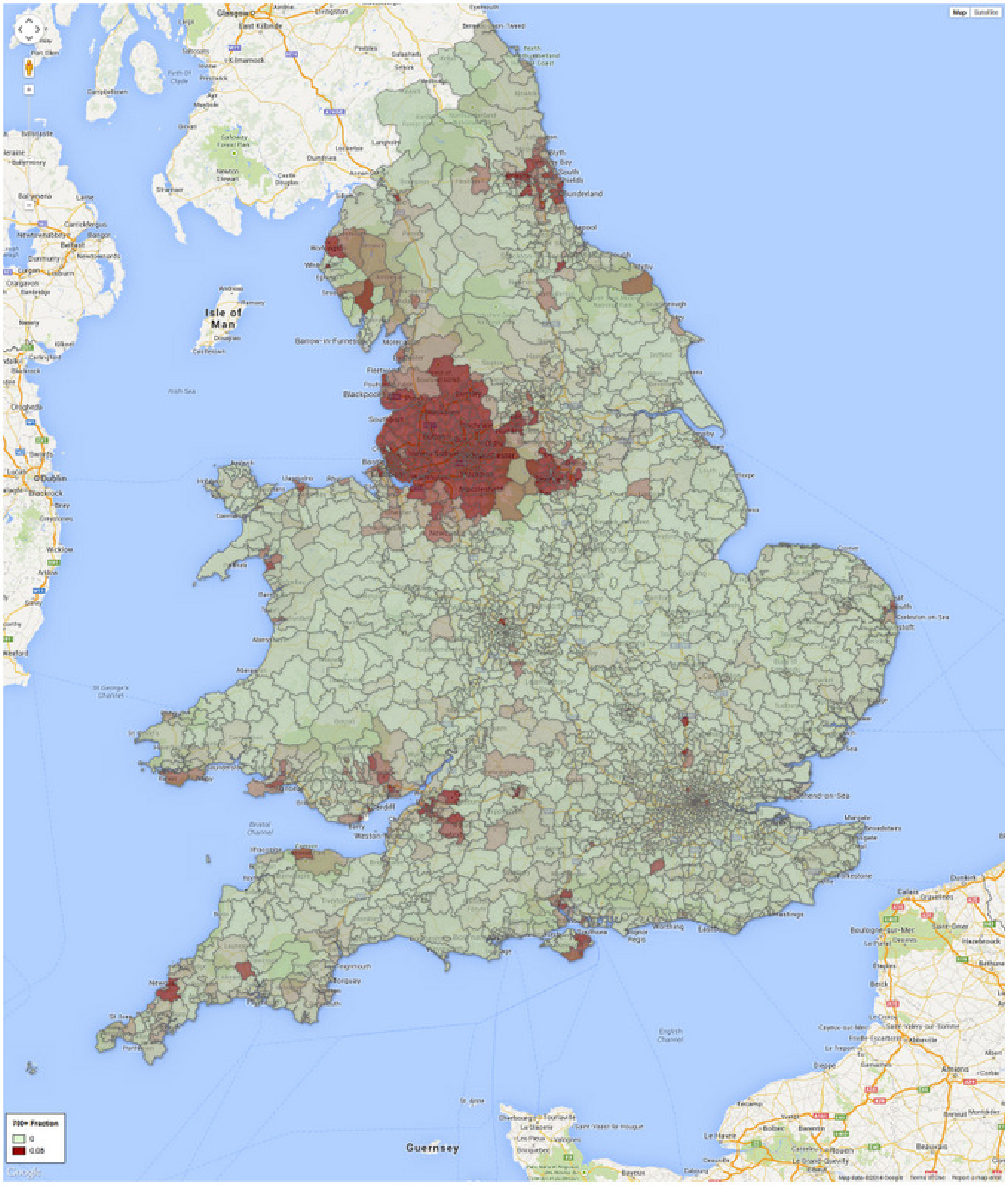
Note: The figure shows the fraction of house transactions with 125-200 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.21: London Houses: Fraction of 125-200 years leaseholds



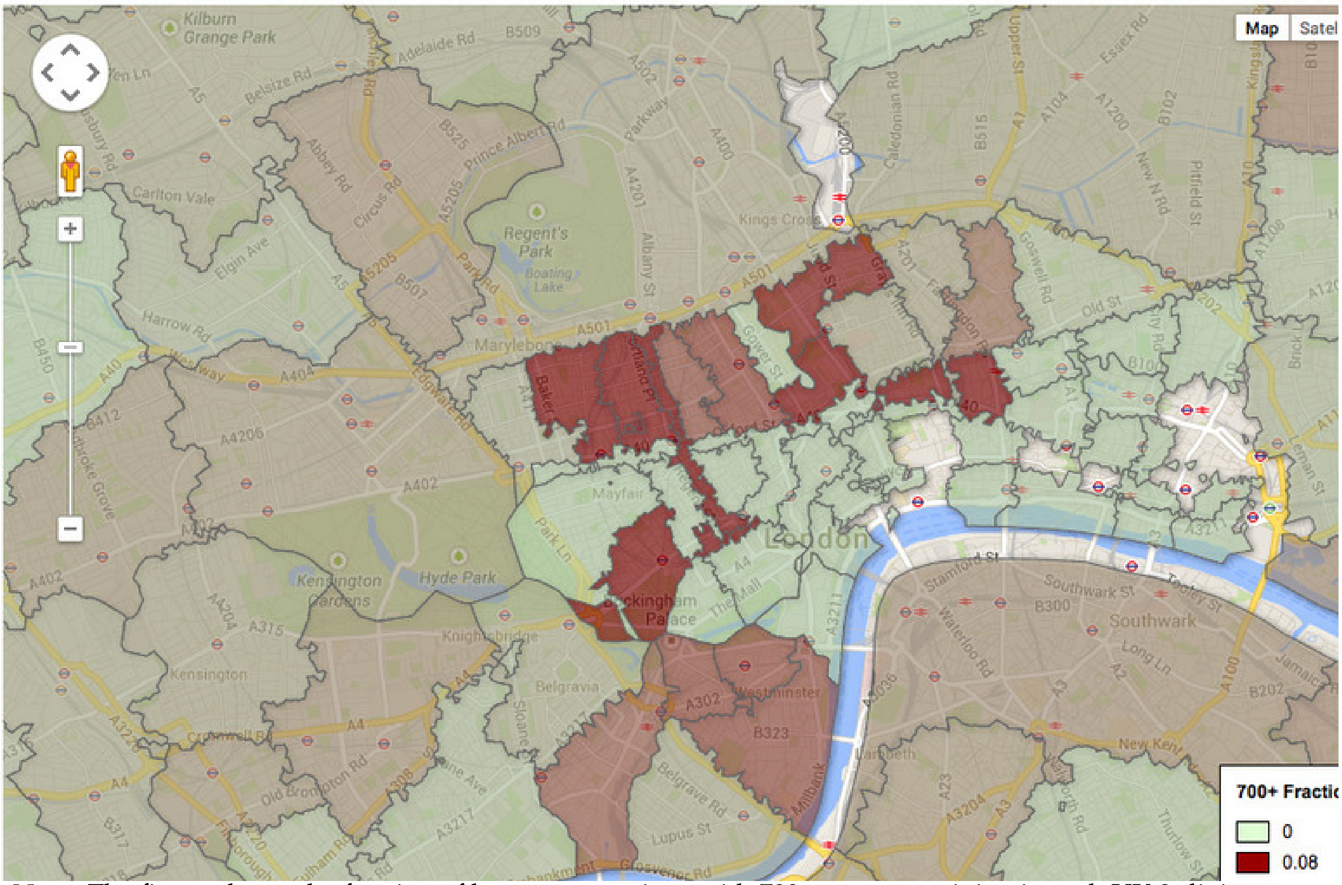
Note: The figure shows the fraction of house transactions with 125-200 years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.22: U.K. Houses: Fraction of 700+ years leaseholds



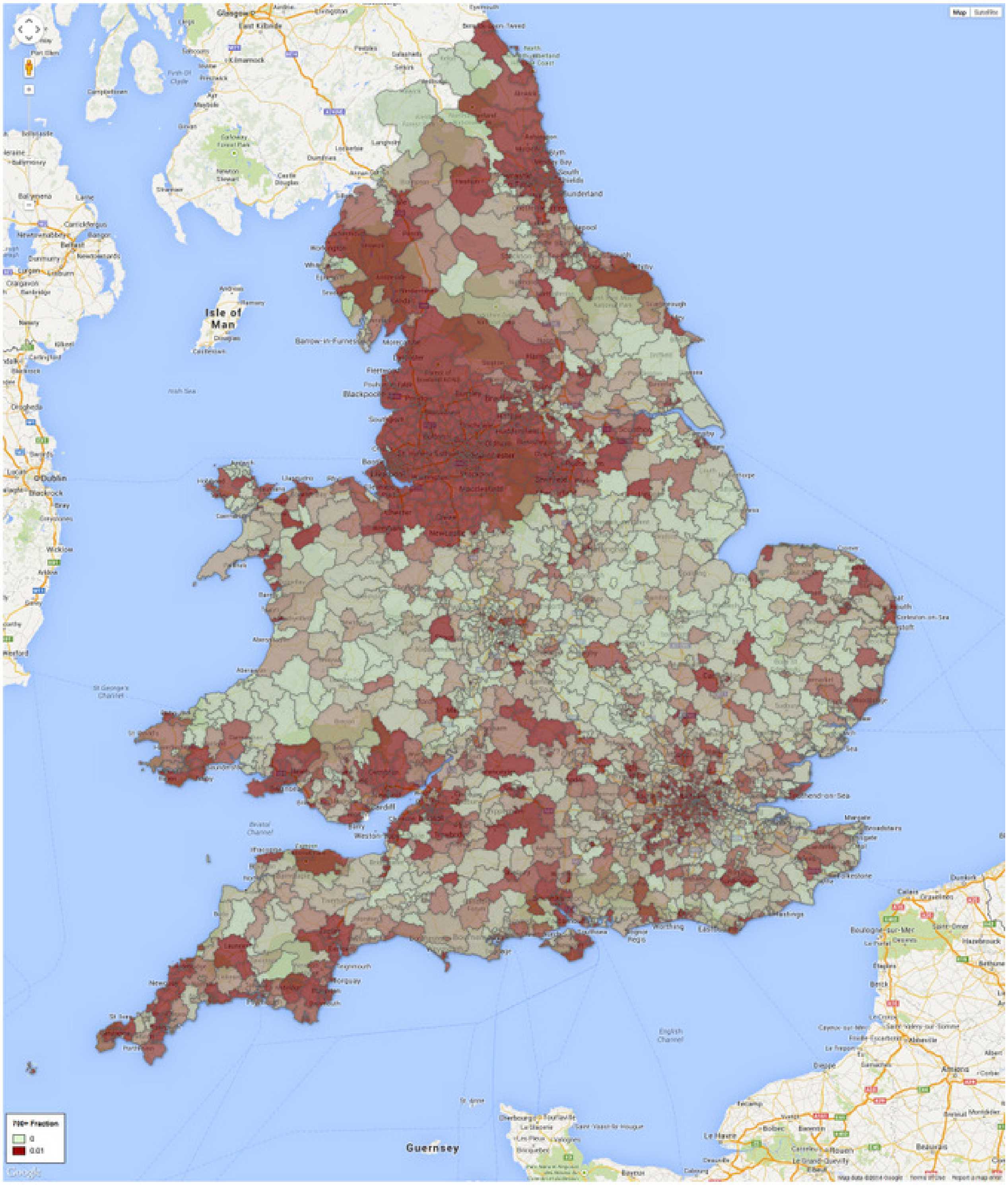
Note: The figure shows the fraction of house transactions with 700+ years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes.

Figure A.23: London Houses: Fraction of 700+ years leaseholds



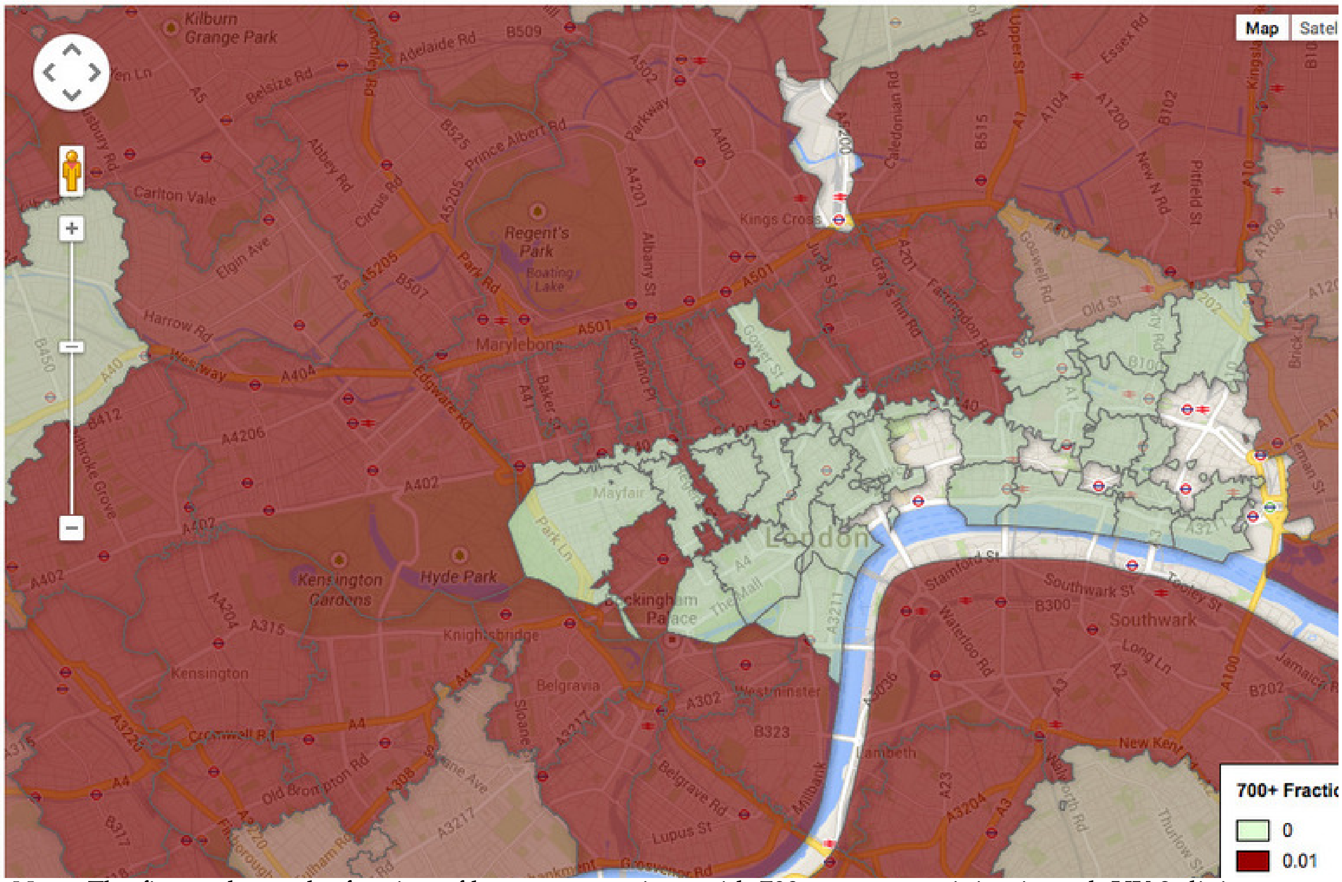
Note: The figure shows the fraction of house transactions with 700+ years remaining in each UK 3-digit postcode. Green and red correspond to the 10th and 90th percentile of the distribution of the fraction across postcodes. The figure zooms in on London.

Figure A.24: U.K. Houses: Fraction of 700+ years leaseholds



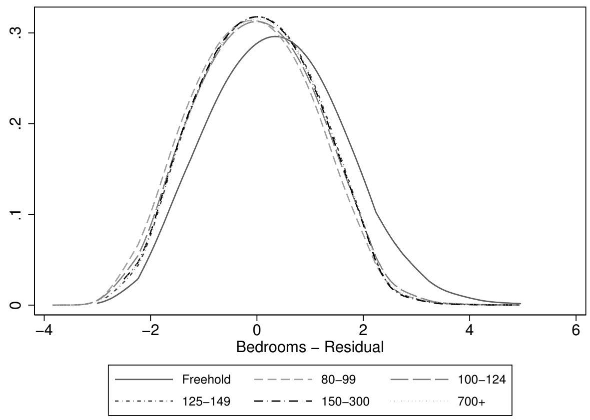
Note: The figure shows the fraction of house transactions with 700+ years remaining in each UK 3-digit postcode. White corresponds to the 10th percentile of the distribution of the fraction across postcodes, while black corresponds to 1%

Figure A.25: London Houses: Fraction of 700+ years leaseholds

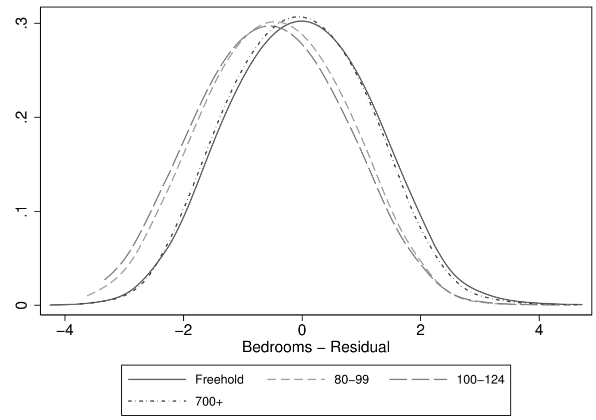


Note: The figure shows the fraction of house transactions with 700+ years remaining in each UK 3-digit postcode. White corresponds to the 10th percentile of the distribution of the fraction across postcodes, while black corresponds to 1%. The figure zooms in on London.

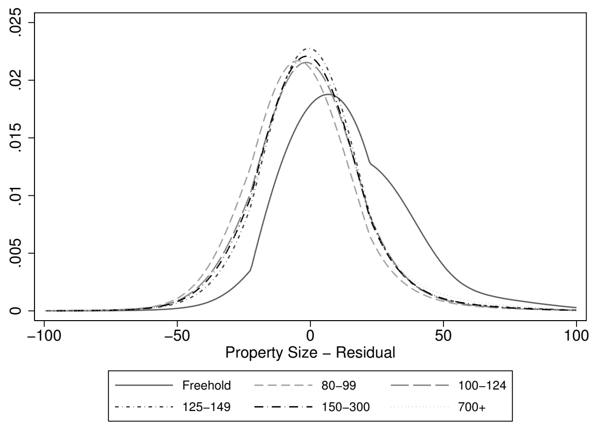
Figure A.26: Hedonic Characteristics by Leasetype - UK Flats



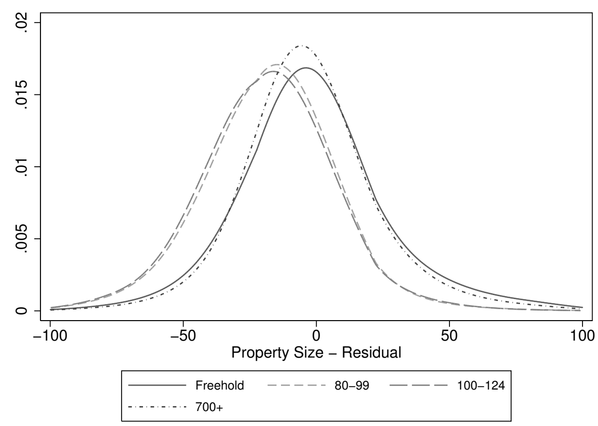
(a) Bedrooms, flats



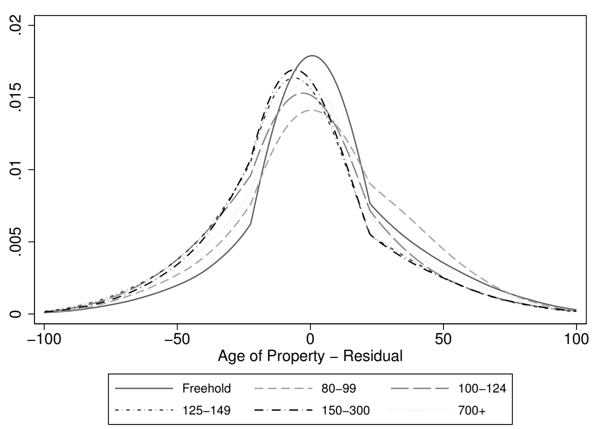
(b) Bedrooms, houses



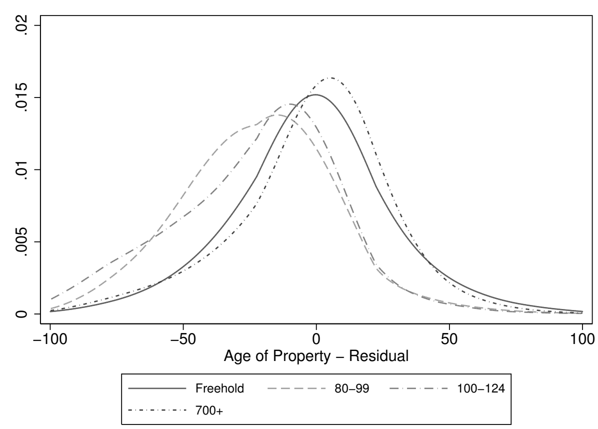
(c) Size, flats



(d) Size, houses



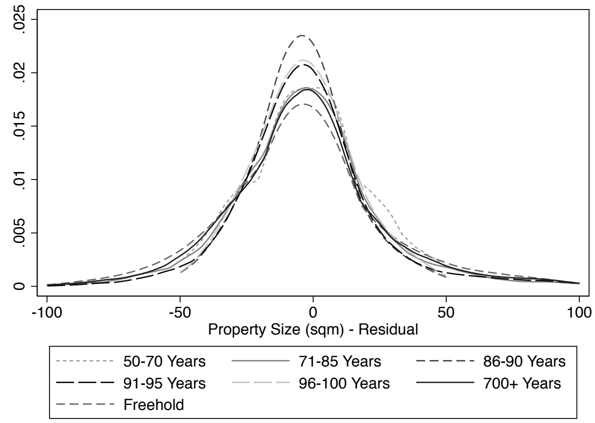
(e) Property Age, flats



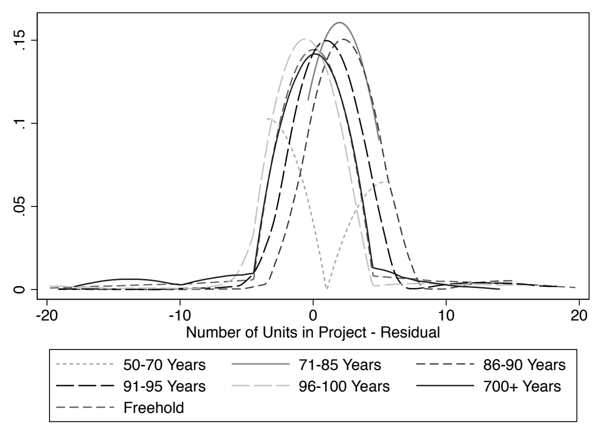
(f) Property Age, houses

Note: This figure shows the distribution of residuals from a regression of property characteristics on property type $\times$ title type (strata or land) $\times$ 3-digit postcode times property type times year fixed effects for leaseholds with different remaining lease maturity and freeholds. The characteristics plotted are: number of bedrooms, size of the property in square meters, age of the property

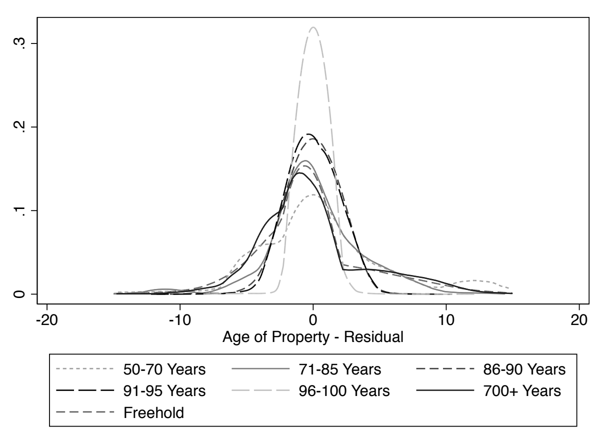
Figure A.27: Hedonic Characteristics by Leasetype - Singapore



(a) Property Size



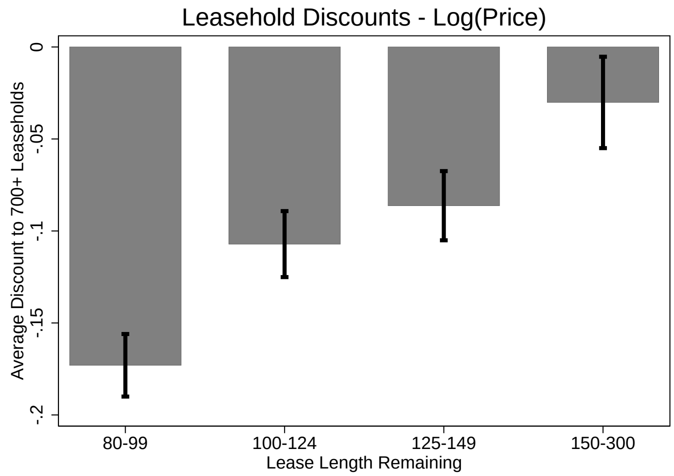
(b) Development Size



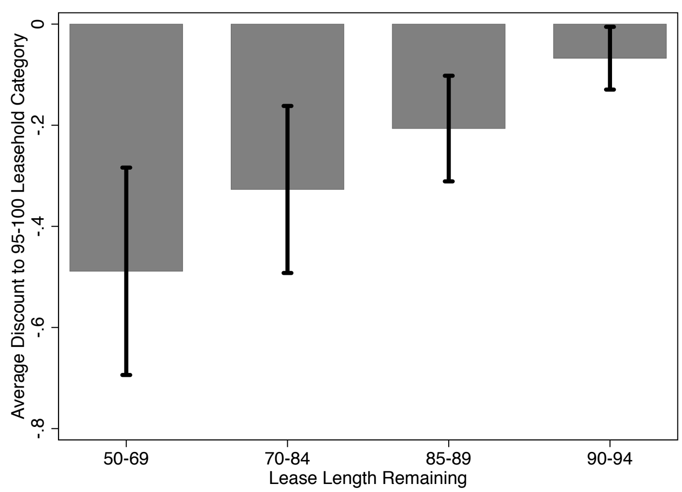
(c) Property Age

Note: This figure shows the distribution of residuals from a regression of property characteristics on property type $\times$ title type (strata or land) $\times$ 5-digit postcode fixed effects for leaseholds with different remaining lease maturity. The top panel shows residuals for the total area in square meters, the middle panel for the total project size and the bottom panel for property age.

Figure A.28: Price Discount by Remaining Lease Length - Within Leasehold Estimates



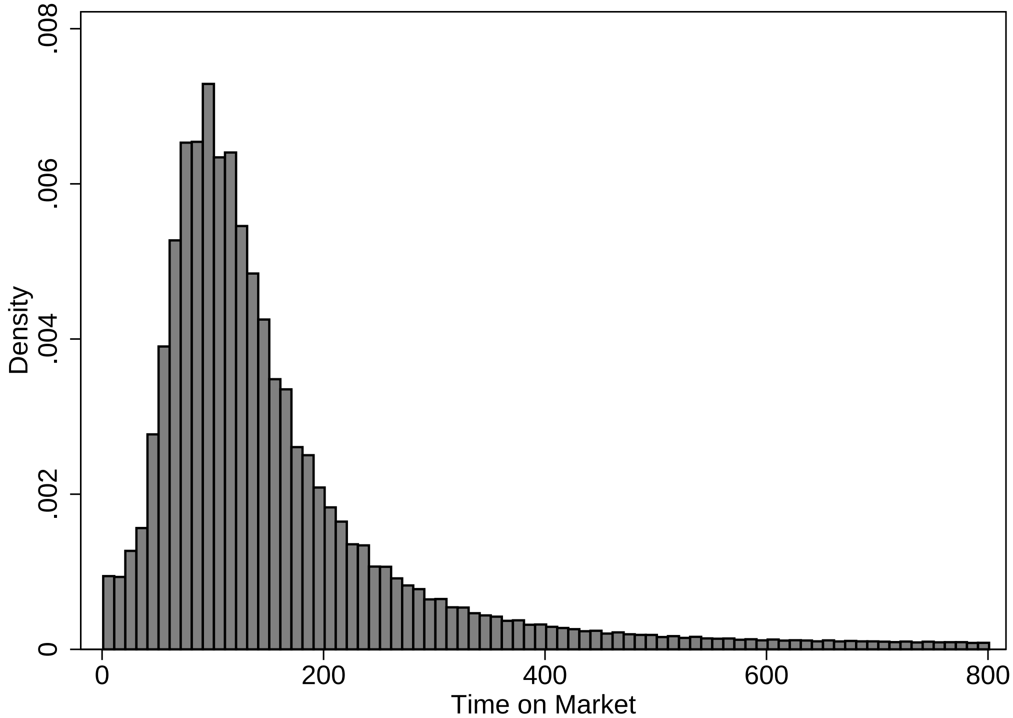
(a) U.K. - Relative to Leases with 700+ years remaining



(b) Singapore - Relative to Leases with 96-100 years remaining

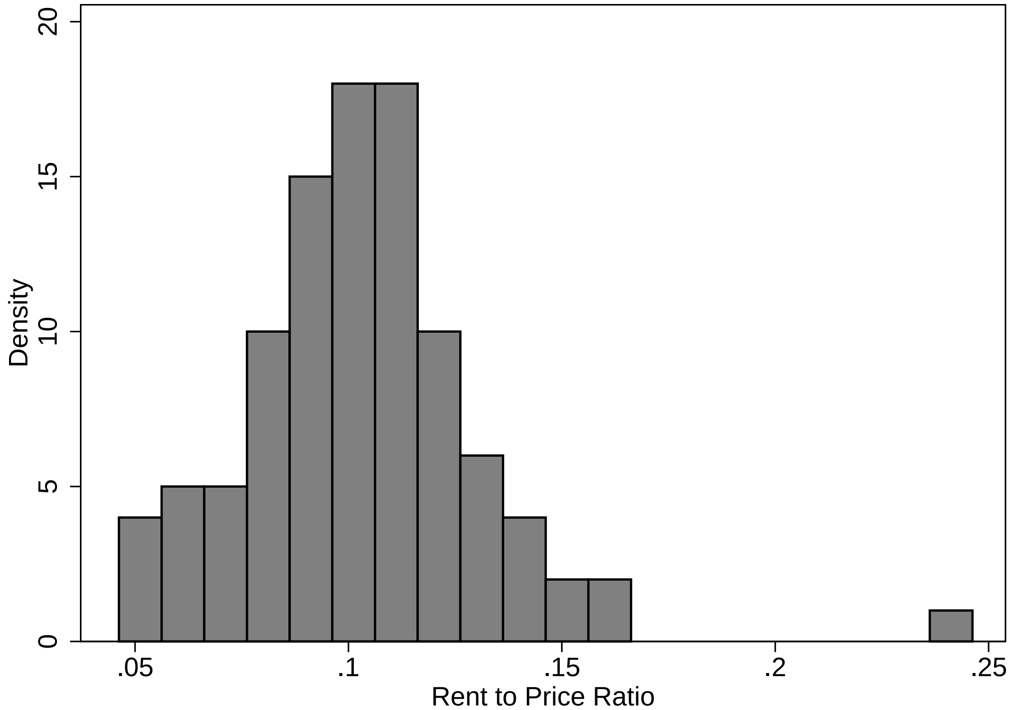
Note: This figure shows β_j coefficients from regression (1) in the top panel and (3) in the bottom panel. In the top panel, which focusses on U.K. transactions, the price discounts are relative to leaseholds with more than 700 years remaining, and correspond to column (1) of Appendix Table A.3. The analysis is conducted only within flats. We include 3-digit post code by transaction year-month fixed effects. We also control for the size, number of bedrooms, bathrooms, property age, property condition, whether there is parking, and the type of heating. The bars indicate the 95% confidence interval of the estimate using standard errors double clustered at the 3-digit postcode and at the year level. In the bottom panel, which focusses on Singapore Transactions, we restrict to an estimation within strata leases with initial lease length of 99 years; the excluded category are those leaseholds with 95-100 years remaining. The dependent variable is the log price foot paid for properties sold by private parties in Singapore between 1995 and 2013, corresponding to Column (2) in Appendix Table 7. We include fixed effect for the 5-digit postcode by property type (apartment, condominium, detached house, executive condominium, semi-detached house and terrace house) by title type (Strata or Land) by transaction month. We control for the age of the property (by including a dummy variable for every possible age in years), the size of the property (by including a dummy for each of 40 equally sized groups capturing property size) and the total number of units in the property. The bars indicate the 95% confidence interval of the estimate using standard errors double clustered by 5-digit postcode and by year.

Figure A.29: Distribution Time on Market



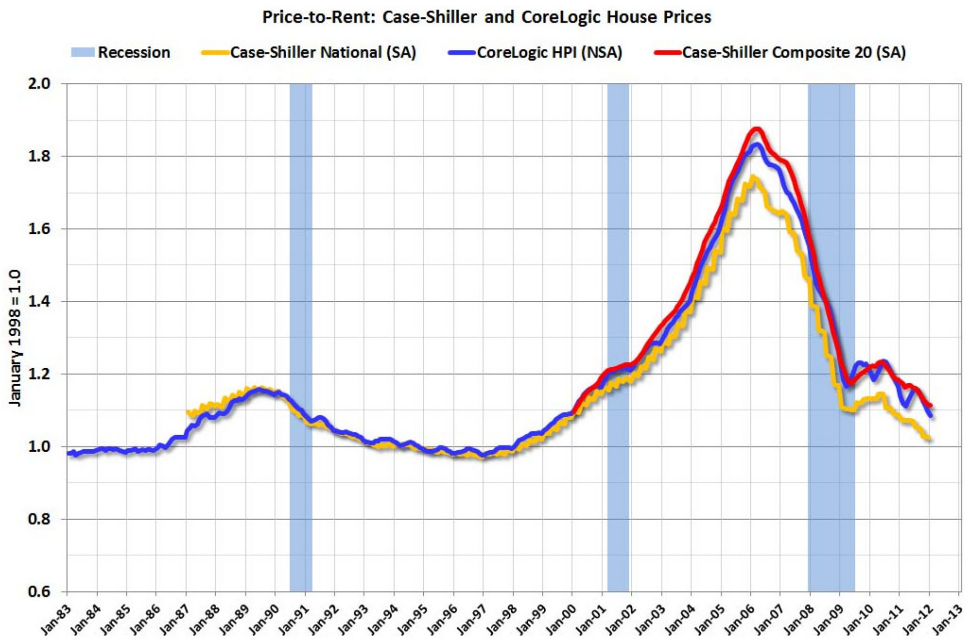
Note: The figure shows the distribution of the time on market observed in our data.

Figure A.30: Cross-Sectional Distribution of Price-Rent Ratio in the U.S.



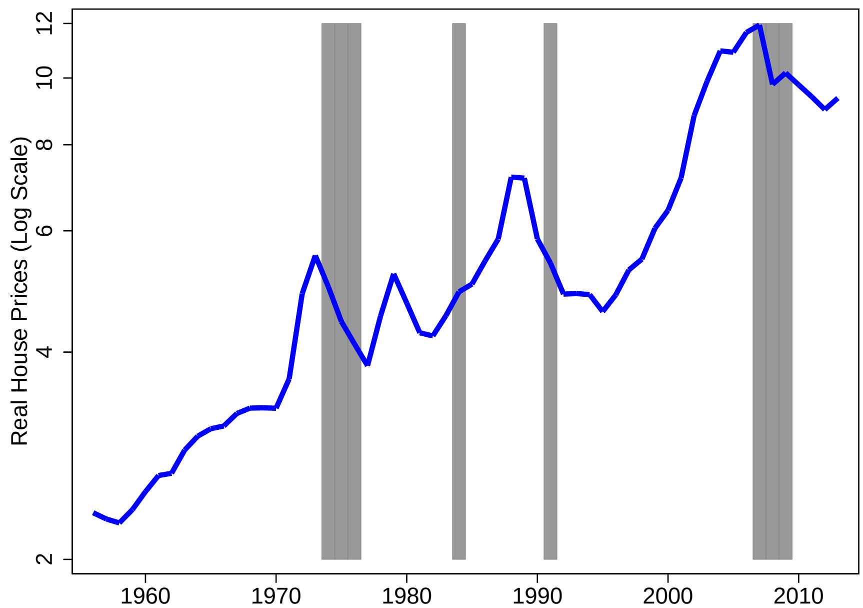
Note: The figure shows the distribution of the rent-to-price ratio for the 100 largest MSAs in the U.S. in September 2013 as constructed by Trulia, which observes a large set of both for-sale and for-rent listings. It is constructed using a metro-level hedonic regression of $\ln(price)$ on property attributes, zipcode fixed effects, and a dummy for whether the unit is for rent. The rent-to-price ratio is constructed by taking the exponent of the coefficient on this dummy variable.

Figure A.31: Price-Rent Ratio Timeseries in the U.S.

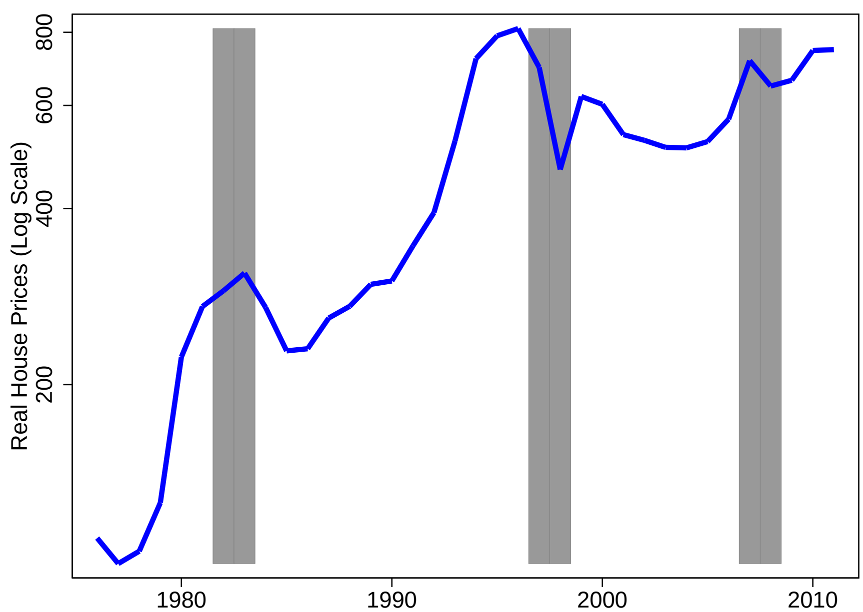


Note: The figure shows the time series of the price-rent ratio in the U.S. as constructed by `http://www.calculatedriskblog.com/`.

Figure A.32: House Price Riskiness II



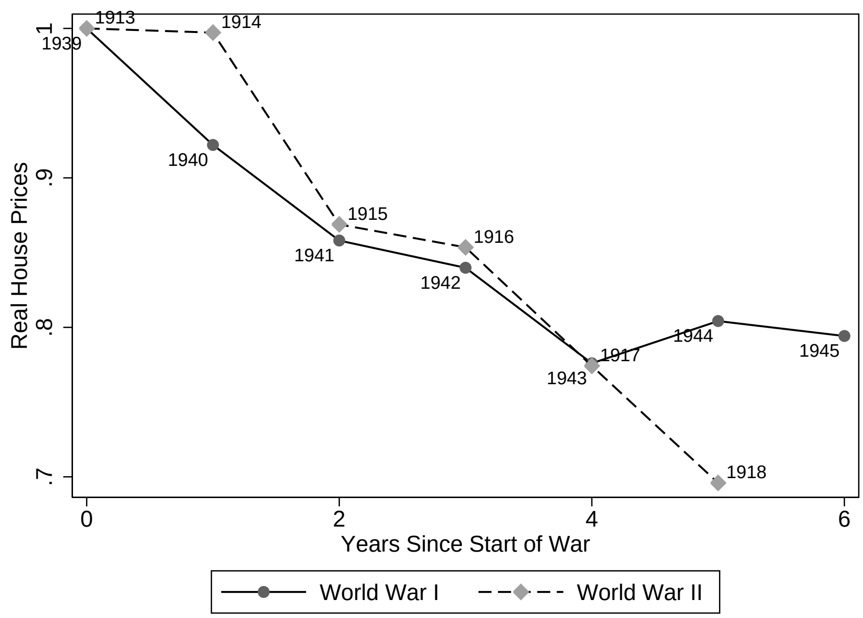
(a) U.K.



(b) Singapore

Note: The figures show the evolution of real house prices in the U.K. (top panel) and Singapore (bottom panel). Shaded regions for the U.K. are financial crises identified by Reinhart and Rogoff (2009): 1974-1976, 1984, 1991 and 2008-2009. Shaded regions for Singapore include the 1982-1983 financial crisis identified by Reinhart and Rogoff (2009), as well as the Asian financial crisis (1997-1998), and the 2007-2008 global financial crisis. See Appendix A.3.3 for a description of the data series studied here.

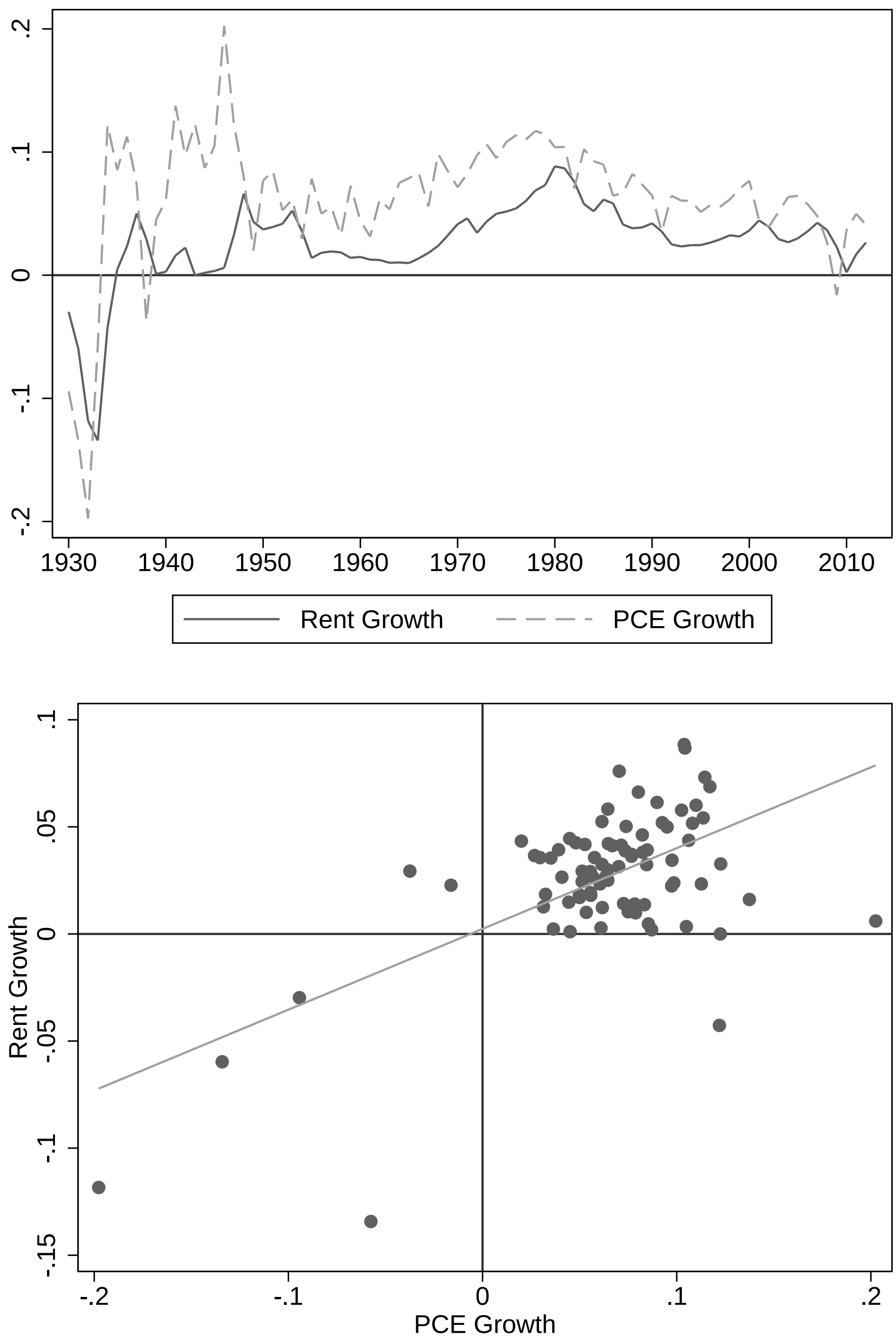
Figure A.33: House Price Riskiness III



(a) Housing During World Wars

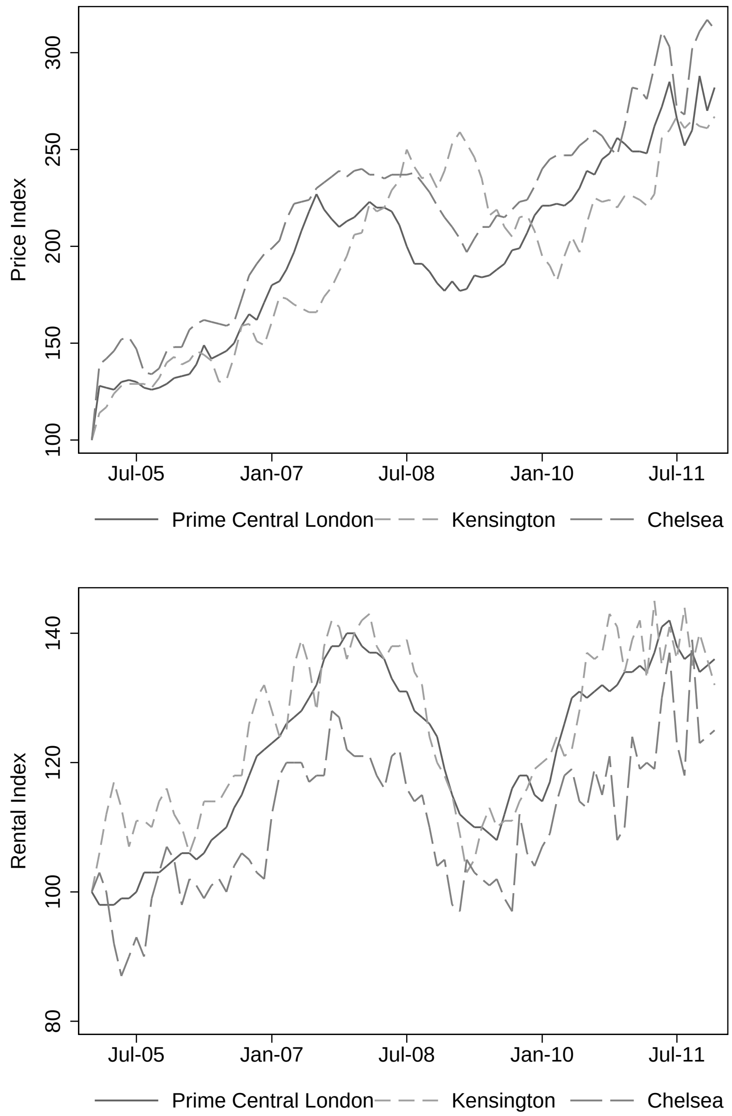
Note: The top panel shows the evolution of real house prices for countries with available house-price time series during World War I (Australia, France, Netherlands, Norway, United States) and World War II (Australia, France, Netherlands, Norway, Switzerland, United States). See Appendix A.3.3 for a description of the data series studied here.

Figure A.34: Rent Growth vs. PCE Growth in U.S.



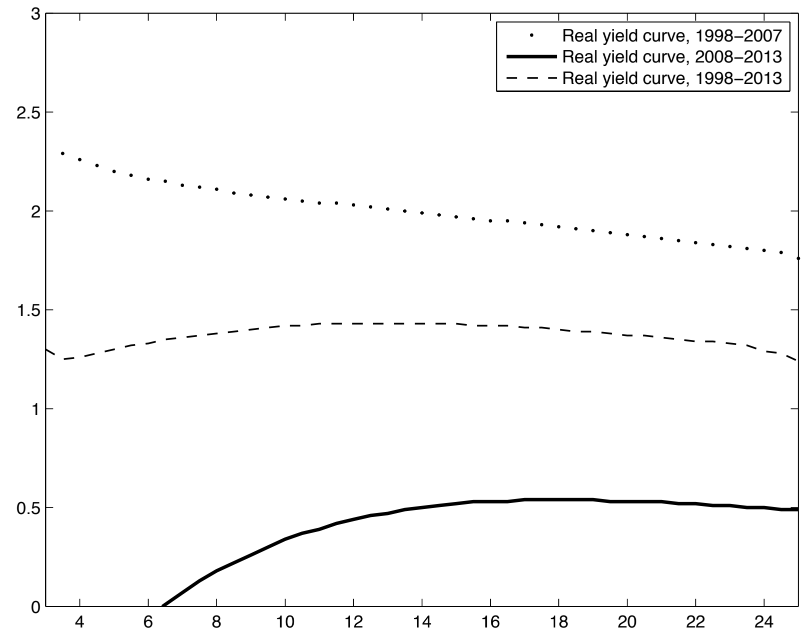
Note: The figure shows the annual growth rates of the "Consumer Price Index for All Urban Consumers: Rent of primary residence" (FRED ID: CUUR0000SEHA) and "Personal Consumption Expenditure" (FRED ID: PCDGA) since 1929.

Figure A.35: House Prices and Rents in Prime Central London Areas during the 2007-09 Financial Crisis



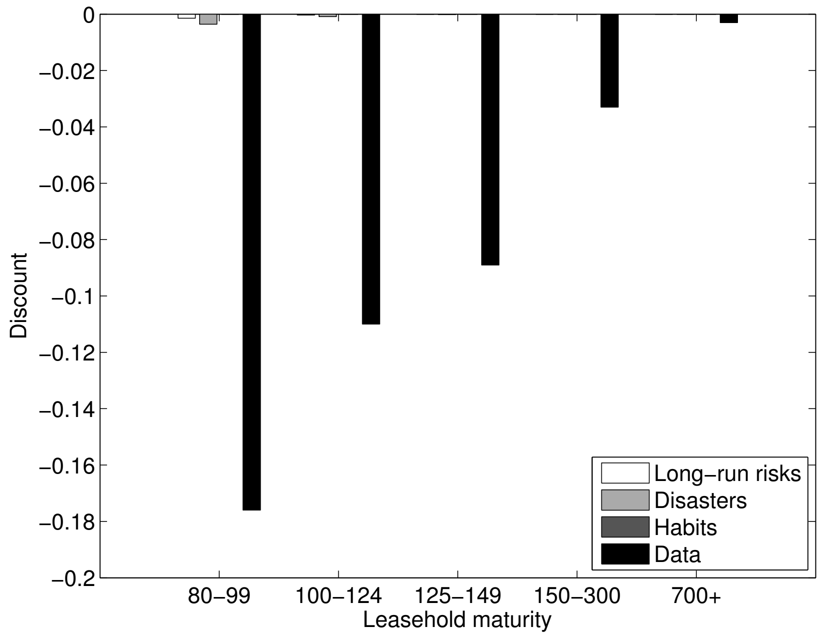
Note: The figure shows the time series of house prices and rents for Prime Central London, Kensington, and Chelsea for the period January 2005 to January 2012. The series are monthly and available from John D Wood & Co. at http://www.johndwood.co.uk/content/indices/london-property-prices/

Figure A.36: UK Gilts Real Yield Curve

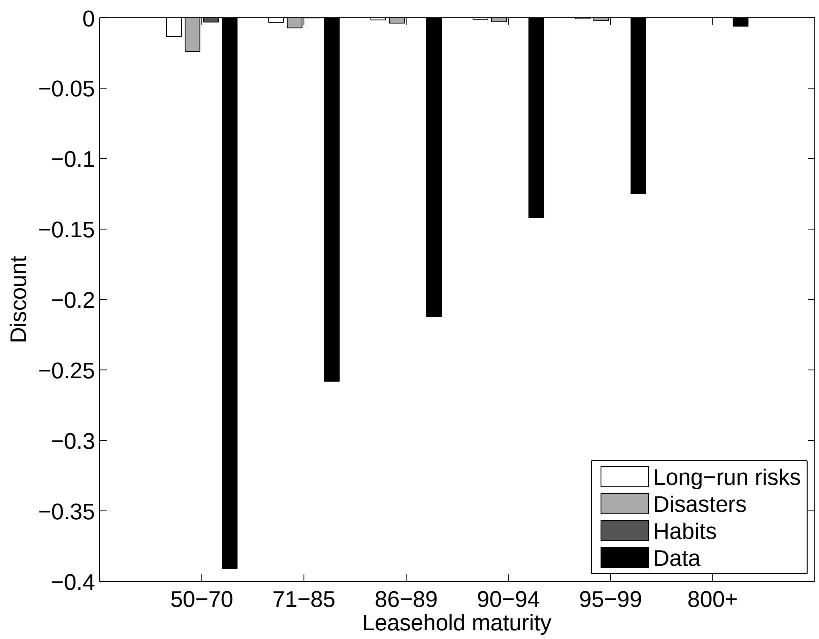


Note: The figure plots the real yield curve for UK gilt bonds as computed by the Bank of England.

Figure A.37: Asset Pricing Models: Model-Implied Discounts vs. Data



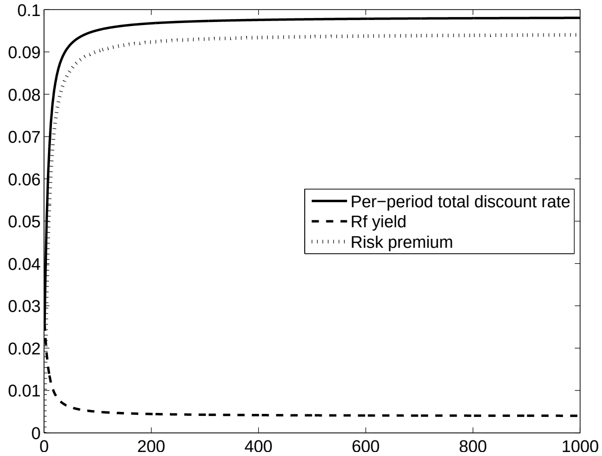
(a) U.K.



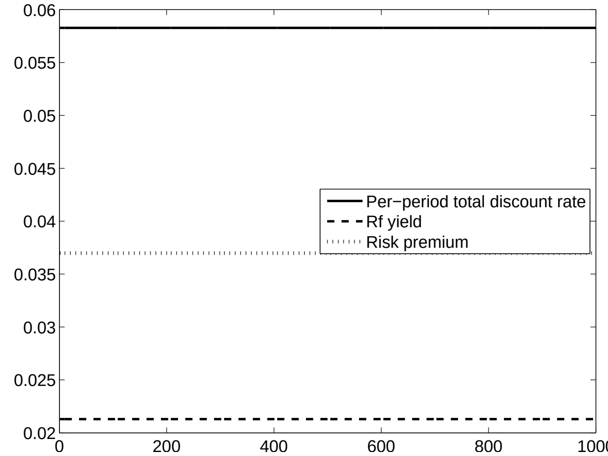
(b) Singapore

Note: The figure shows the discounts for leaseholds observed in the U.K. (top panel) and Singapore (bottom panel) together with discounts implied by the long-run risk model, the variable rare-disaster model, and the habit-formation model. The calibrations impose that housing has expected return of 6.5% and growth rate of rents of 0.7%.

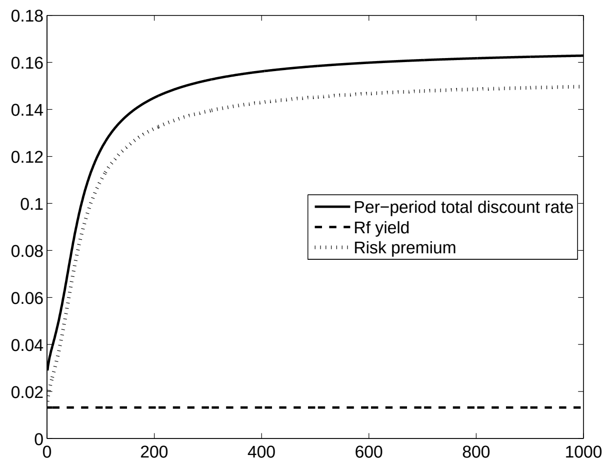
Figure A.38: Asset Pricing Models: Discount Rates by Maturity



(a) Long-run risks



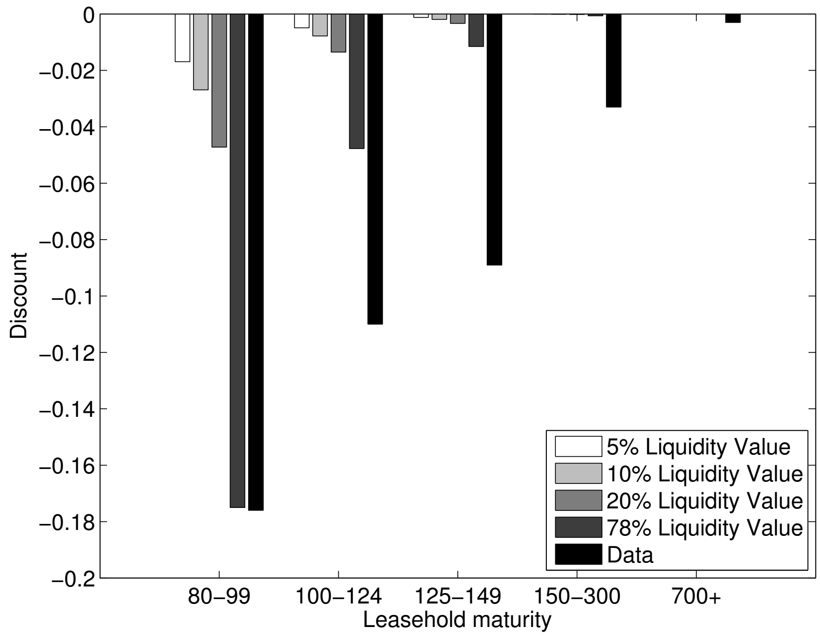
(b) Disasters



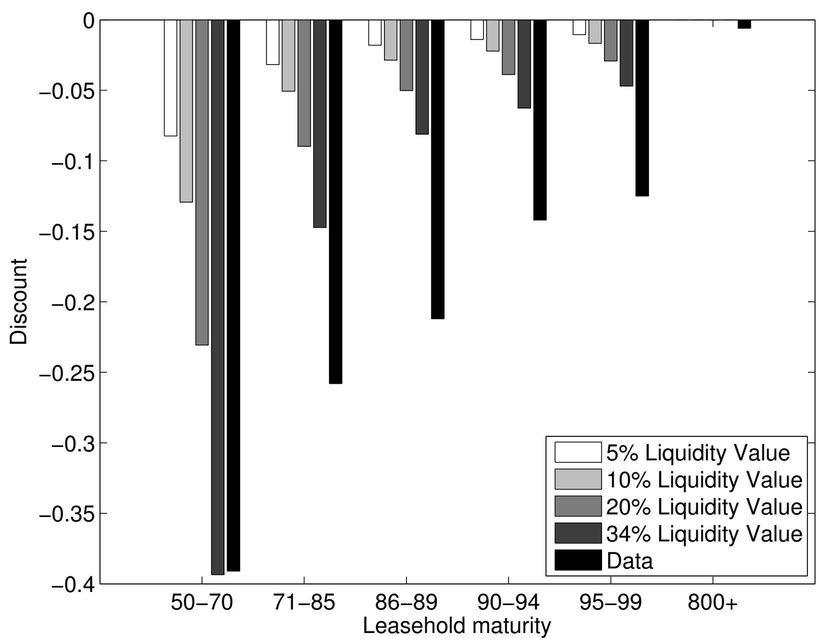
(c) Habits

Note: Total per-period discount rates, risk-free yields, and risk premia for leading asset pricing models.

Figure A.39: Financing-Frictions Reduced-Form Model: Model-Implied Discounts vs. Data



(a) U.K.



(b) Singapore

Note: The figure shows the discounts for leaseholds observed in the U.K. (top panel) and Singapore (bottom panel) together with discounts implied by a parameterizations of the financing-friction reduced form model in Section 6.1 using $r = 6.5\%$, $g = 0.7\%$, and different values of α. The last value of α is chosen so that the shorter-maturity discount is matched exactly.

Appendix Tables

Table A.1: Summary Statistics U.K.: Fraction of leaseholds and freeholds by postcode

Houses	Mean	Std	10th perc	25th perc	Median	75th perc	90th perc
% Freeholds	0.943	0.128	0.857	0.966	0.986	0.993	0.997
% 80-99	0.008	0.021	0	0.001	0.003	0.007	0.015
% 100-124	0.008	0.032	0	0.001	0.003	0.006	0.012
% 125-200	0.003	0.020	0	0	0	0.001	0.003
% 700+	0.039	0.114	0	0.001	0.004	0.014	0.078

Flats	Mean	Std	10th perc	25th perc	Median	75th perc	90th perc
% Freeholds	0.076	0.133	0.009	0.018	0.038	0.076	0.164
% 80-99	0.177	0.157	0.006	0.052	0.145	0.263	0.388
% 100-124	0.322	0.191	0.070	0.182	0.322	0.440	0.562
% 125-149	0.069	0.077	0	0.021	0.051	0.088	0.153
% 150-300	0.052	0.094	0	0	0.017	0.058	0.138
% 700+	0.304	0.229	0.042	0.126	0.259	0.443	0.636

Note: This table shows descriptive statistics on the fractions of freeholds and leaseholds of each maturity bucket by 3-digit U.K. postcode.

Table A.2: U.K.: Impact of Lease Type on Prices - Houses

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lease Length Remaining							
80-99 Years	-0.375***	-0.378***	-0.379***	-0.375***	-0.364***	-0.332***	-0.374***
	(0.026)	(0.025)	(0.025)	(0.025)	(0.024)	(0.022)	(0.027)
100-124 Years	-0.296***	-0.298***	-0.298***	-0.297***	-0.286***	-0.273***	-0.290***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.017)
$>$ 700 Years	-0.012**	-0.012**	-0.012**	-0.012**	-0.011*	-0.007	-0.011*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)
Fixed Effects	PC $\times$ M	PC $\times$ Q	PC $\times$ Y	PC $\times$ M	PC $\times$ M	PC $\times$ M	PC $\times$ M
Controls	✓	✓	✓	✓, $\times$ year	✓	✓	✓
Restrictions	·	·	·	·	Wisorize Price	Nonmiss. Hedonics	Exclude London
R-squared	0.783	0.781	0.777	0.785	0.790	0.820	0.765
N	6,628,133	6,628,133	6,628,133	6,628,133	6,628,133	5,453,962	6,393,099

Note: This table shows results from regression (1) estimated for houses. The dependent variable is log price, for properties sold in England and Wales between 2004 and 2013. To convert into percentage discounts for leasehold properties we compute $e^{\beta_j} - 1$.We include 3-digit postcode by transaction time fixed effects. In columns (2) and (3) the transaction time is the transaction quarter and year, respectively, in the other columns the transaction month. In column (4) we interact the controls with the transaction year. In column (5) we winsorize the price at the 1st and 99th percentile, in column (6) we only include properties for which characteristics are not missing, and in column (7) we exclude transactions in London. We also control for the size, number of bedrooms, bathrooms, property age, property condition, whether there is parking, and the type of heating. Standard errors are clustered at the level of the fixed effect. Significance Levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

Table A.3: U.K.: Impact of Lease Type on Prices - Flats, relative to 700+ year leaseholds

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lease Length Remaining							
80-99 Years	-0.173***	-0.173***	-0.174***	-0.172***	-0.165***	-0.144***	-0.170***
	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.010)
100-124 Years	-0.107***	-0.104***	-0.101***	-0.105***	-0.100***	-0.099***	-0.069***
	(0.009)	(0.008)	(0.008)	(0.009)	(0.009)	(0.010)	(0.007)
125-149 Years	-0.086***	-0.084***	-0.081***	-0.085***	-0.078***	-0.074***	-0.056***
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)
150-300 Years	-0.030**	-0.031***	-0.030**	-0.029***	-0.024*	-0.015	-0.008
	(0.013)	(0.012)	(0.011)	(0.0012)	(0.012)	(0.012)	(0.012)
Fixed Effects	PC × M	PC × Q	PC × Y	PC × M	PC × M	PC × M	PC × M
Controls	✓	✓	✓	✓, × year	✓	✓	✓
Restrictions	·	·	·	·	Wisorize Price	Nonmiss. Hedonics	Exclude London
R-squared	0.732	0.724	0.714	0.733	0.740	0.778	0.620
N	1,338,244	1,338,244	1,338,244	1,338,244	1,338,244	931,198	996,907

Note: This table shows results from regression (1) estimated for flats, excluding freeholds and computing the discounts relative to the 700+ leaseholds. The dependent variable is log price, for properties sold in England and Wales between 2004 and 2013. To convert into percentage discounts for leasehold properties we compute $e^{\beta_j} - 1$. We include 3-digit postcode by transaction time fixed effects. In columns (2) and (3) the transaction time is the transaction quarter and year, respectively, in the other columns the transaction month. In column (4) we interact the controls with the transaction year. In column (5) we winsorize the price at the 1st and 99th percentile, in column (6) we only include properties for which characteristics are not missing, and in column (7) we exclude transactions in London. We also control for the size, number of bedrooms, bathrooms, property age, property condition, whether there is parking, and the type of heating. Standard errors are double clustered by 3-digit postcode and by year. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

Table A.4: Impact of Lease Type on Log(Price) - Singapore, Relative to 96-100 Year Lease

	RELATIVE TO 96-100 YEAR LEASES			
	(1)	(2)	(3)	(4)
Lease Length Remaining				
50-70 Years	-0.376***	-0.469***	-0.489***	-0.599***
	(0.105)	(0.098)	(0.105)	(0.151)
71-85 Years	-0.348***	-0.358***	-0.327***	-0.325***
	(0.075)	(0.084)	(0.084)	(0.092)
86-90 Years	-0.221***	-0.223***	-0.207***	-0.196***
	(0.046)	(0.047)	(0.053)	(0.054)
91-95 Years	-0.058	-0.072**	-0.067**	-0.056
	(0.039)	(0.028)	(0.032)	(0.043)
Fixed Effects	PC × Y × Prop Type × Title Type	PC × Q × Prop Type × Title Type	PC × M × Prop Type × Title Type	PC × M × Prop Type × Title Type
Controls	✓	✓	✓	✓
Restrictions	·	·	·	New Only
R-squared	0.955	0.967	0.970	0.969
N	172,690	172,690	172,690	82,408

Note: This table shows results from regression (3). To convert into percentage discounts for leasehold properties relatives to freeholds, construct $e^{\beta_j} - 1$. The dependent variable is the price paid for strata properties with initially 99-year leases sold by private parties in Singapore between 1995 and 2013. The excluded category is for transactions with leases with 96-100 years remaining. We include fixed effect at the 5-digit postcode by property type (apartment, condominium, detached house, executive condominium, semi-detached house and terrace house) by title type (Strata or Land) by transaction date. In column (1), the transaction date interaction is for the transaction quarter, in columns (2) - (6) the transaction month. We control for the age of the property (by including a dummy variable for every possible age in years), the size of the property (by including a dummy for each of 40 equally sized groups capturing property size), and the total number of units in the property. In column (3) we only focus on properties that were bought by a private individual (and not the HDB); in column (4) we only focus on properties that were built within the last 3 years of our transaction date. In columns (5) and (6) we conduct the analysis for Strata and non-Strata titles separately. Standard errors are double clustered by 5-digit postcode and by year. Significance Levels: * (p<0.10), ** (p<0.05), *** (p<0.01).

Table A.5: Rent-Price Ratio Singapore - 2012

	(1)	(2)	(3)	(4)
For-Rent Dummy	-3.095***	-3.131***	-3.123***	-3.107***
	(0.044)	(0.019)	(0.014)	(0.025)
Fixed Effects	Quarter × Postal Code	Quarter × Postal Code	Month × Postal Code	Month × Postal Code × Bedrooms
Controls	·	✓	✓	✓
Implied Rent-Price Ratio	4.5%	4.4%	4.4%	4.5%
R-squared	0.804	0.873	0.872	0.872
N	106,145	105,189	105,189	105,189

Note: This table shows results from regression (A.2). To convert into rent-price ratios, we take e^{β}. The dependent variables is the price (for-sale price or annualized for-rent price) for properties listed on iProperty.com in Singapore in 2012. Fixed effects are included as indicated. In columns (2) and (4) we also control for characteristics of the property: we include dummy variables for the type of property (condo, house, etc.), indicators for the number of bedrooms and bathrooms, property age, property size (by adding dummy variables for 50 equal-sized buckets), information on the kitchen (ceramic, granite, etc.), which floor the property is on and the tenure type for leaseholds. Standard errors are clustered at the level of the fixed effect. Significance Levels: * ($p<0.10$), ** ($p<0.05$), *** ($p<0.01$).

Table A.6: House Prices, Banking Crises, Rare Disasters

	House Price Index Time Period	Banking Crises	Rare Disasters
Australia	1880 - 2013	1893, 1989	1918, 1932, 1944
Belgium	1975 - 2012	2008	
Canada	1975 - 2012		
Denmark	1975 - 2012	1987	
Finland	1975 - 2012	1991	1993
France	1840 - 2010	1882, 1889, 1907, 1930, 2008	1871, 1915, 1943
Germany	1975 - 2012	2008	
Japan	1975 - 2012	1992	
Ireland	1975 - 2012	2007	NA
Italy	1975 - 2012	11990, 2008	
Netherlands	1649 - 2010	1893, 1907, 1921, 1939, 2008	1893, 1918, 1944
New Zealand	1975 - 2012	1987	
Norway	1819 - 2013	1899, 1922, 1931, 1988	1918, 1921, 1944
Singapore	1975 - 2012	1982	
Spain	1975 - 2012	1978, 2008	
South Africa	1975 - 2012	1977, 1989	NA
South Korea	1975 - 2012	1986, 1997	1998
Sweden	1952 - 2013	1991, 2008	
Switzerland	1937 - 2012	2008	1945
U.K.	1952 - 2013	1974, 1984, 1991, 2007	
U.S.	1890 - 2012	1893, 1907, 1929, 1984, 2007	1921, 1933

Note: The table shows time series availability for house price indices in the second column. The third and fourth column report dates of banking crises or consumption rare disasters if any occur for the country in the time period provided in the first column. Banking crises dates for all countries, except Singapore, Belgium, Finland, Ireland, New Zealand, South Korea, and South Africa, are from Schularick and Taylor (2012). Banking crises dates for the countries not covered by Schularick and Taylor (2012) are from Reinhart and Rogoff (2009). Rare disasters dates are the year of the trough in consumption during a consumption disaster as reported by Barro et al. (2008). NA means that the country is not covered by the source dataset.

Table A.7: Time Series Properties of Real House Price Growth

	Real HP Growth		Real PDI Growth		
	Mean	Std. Dev.	Mean	Std. Dev.	Correlation
Australia	3.20%	6.89%	1.43%	2.77%	0.093
Belgium	2.80%	5.87%	1.17%	2.27%	0.436
Canada	2.51%	7.63%	1.37%	2.10%	0.489
Switzerland	0.94%	4.73%	1.12%	1.63%	0.445
Germany	-0.29%	2.31%	1.27%	1.70%	0.288
Denmark	1.57%	8.99%	1.09%	2.29%	0.211
Spain	2.05%	8.26%	0.83%	2.46%	0.631
Finland	2.04%	8.19%	2.07%	3.21%	0.482
France	2.52%	5.23%	1.22%	1.58%	0.358
U.K.	3.53%	8.54%	2.20%	2.74%	0.355
Ireland	3.70%	9.73%	1.83%	3.59%	0.529
Italy	0.60%	8.28%	0.82%	2.44%	0.325
Japan	-0.24%	4.28%	1.55%	1.40%	0.587
S. Korea	0.59%	7.70%	3.95%	4.58%	0.235
Luxembourg	3.94%	6.68%	2.84%	3.75%	0.054
Netherlands	2.32%	9.43%	0.48%	3.25%	0.472
Norway	2.76%	7.23%	2.22%	2.52%	0.064
New Zealand	2.20%	7.73%	0.98%	3.45%	0.530
Sweden	1.50%	7.27%	1.34%	2.28%	0.431
U.S.	1.13%	3.89%	1.60%	1.56%	0.371
S. Africa	0.88%	9.65%	0.53%	3.05%	0.373

Note: This table shows time series properties of quarterly frequency annual growth rats of real house prices and personal disposable income between 1975 and Q2 2013, as collected by Mack and Martínez-García (2011*b*). Columns (1) and (2) show the mean and standard deviation of real house price growth. Columns (3) and (4) the mean and standard deviation of real personal disposable income growth. Column (5) shows the correlation of real house price growth with real personal disposable income growth.