NBER WORKING PAPER SERIES

VERY LONG-RUN DISCOUNT RATES

Stefano Giglio
Matteo Maggiori
Johannes Stroebel

Working Paper 20133
http://www.nber.org/papers/w20133

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2014

We thank Sumit Agarwal, John Campbell, Raj Chetty, John Cochrane, Xavier Gabaix, Bob Goldstein, Christian Gollier, Bob Hall, Barney Hartman-Glaeser, Mervyn King, Anil Kashyap, Amir Kermani, Ralph Koijen, Martin Lettau, Hanno Lustig, Tim McQuade, William Nordhaus, Arthur van Benthem, Jules van Binsbergen, Stijn van Nieuwerburgh, Monika Piazzesi, Tomasz Piskorski, Tarun Ramadorai, Amit Seru, Martin Weitzman as well as seminar participants at the NBER (Public Economics, Asset Pricing, Financing Housing Capital), Harvard (HBS and Department), Princeton (JRC Conference), Chicago Booth, NYU Stern, Adam Smith Conference (LBS/LSE/Oxford), UBC Winter Finance Conference, ASU Sonoran Winter Finance Conference, HULM Conference, and Notre Dame for helpful discussions. We gratefully acknowledge the generous research support from the NYU Stern Center for the Global Economy and Business as well as from the Fama-Miller Center and the Initiative on Global Markets at the University of Chicago Booth School of Business. We thank Brent Ambrose, Mihnea Constantinescu, Piet Eichholtz, Marc Francke, Thies Lindenthal, Niclas Sjölund, Nigel Stapledon as well as Trulia, iProperty, and Rightmove for sharing part of their data. We thank Miguel de Faria e Castro for excellent research assistance. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Very Long-Run Discount Rates
Stefano Giglio, Matteo Maggiori, and Johannes Stroebel
NBER Working Paper No. 20133
May 2014
JEL No. E44,G11,G12,R30

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 99 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 more than 10% less than otherwise identical freeholds, implying discount rates below 2.6% for 100-year claims. Given the riskiness of rents, this suggests that both long-run risk-free discount rates and long-run risk premia are low. We show how the estimated very long-run discount rates are informative for climate change policy.

Stefano Giglio
University of Chicago
Booth School of Business
5807 S. Woodlawn Avenue
Chicago, IL 60637
and NBER
stefano.giglio@chicagobooth.edu

Matteo Maggiori
Stern School of Business
New York University
44 West Fourth Street, 9-78
New York, NY 10012
and NBER
matteo.maggiori@stern.nyu.edu

Johannes Stroebel
New York University
Leonard N. Stern School of Business
44 West 4th Street, KCM 9-98
New York, NY 10012
johannes.stroebel@nyu.edu

An online appendix is available at:
http://www.nber.org/data-appendix/w20133

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, 2007; Weitzman, 2007; Gollier, 2006; Barro, 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 99 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 a unique and 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. This is confirmed by a direct, systematic analysis of the covenants in a subset of leasehold contracts. 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. Our estimates also cannot be explained by potential financing frictions that might be important for short-maturity leasehold properties (50-70 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 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 observed 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 leaseholds relative to freeholds. Intuitively, given the low long-run growth rates of rents, 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 to housing, but sufficiently low in the long run to match the observed prices of very long-run cash flows. These patterns imply a low long-run risk-free discount rate, and a

[1] In Section 5.1 we derive both formulas explicitly. Here we focus on the related intuition.

low long-run risk premium for rents. Since rents are risky, they also imply a low long-run price of risk. This result is complementary to the recent 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, 2012; Weitzman, 2001, 2013; Pindyck, 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 (2007), who argued that private markets reveal discount rates well above zero. For example, Nordhaus (2007) 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. While the direct implications of our findings for climate change policy depend on the relative risk properties of real estate and climate change investment, the low price of long-run risk makes optimal climate change policy less sensitive than previously believed to the long-run β of the proposed investments.

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 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. A recent literature inspired by Binsbergen, Brandt and Koijen (2012) includes Belo, Collin-Dufresne and Goldstein (2012), Ai et al. (2012) and Boguth et al. (2011).

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 on each of these.

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 (Burn, Cartwright and Cheshire, 2011). Common initial leasehold maturities are 99, 125, 150, 250 or 999 years. During this period, ownership of the leasehold 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 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 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 in exchange for paying a premium, 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. In Section 3.7, 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 potentially stronger negotiating power of freeholders with laws and court decisions that are favorable towards the leaseholder.

Some leaseholds contain covenants that might, for example, restrict the type of commercial activity that can be operated on the land. In Section 3.2 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 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 almost always have initial terms of 99 years or 999 years. 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 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.

2.1 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 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.

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 transaction but is only registered afterwards. We have manually detected a number of such instances in a subsample of leasehold 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.[3]

For 80% of the properties, we have obtained additional proprietary property characteristics such as the number of bedrooms, bathrooms, the size and age of the property as well as information on the condition, type of heating and availability of parking. These are collected by Righmove.co.uk from "for sale" listings and other data sources. Rightmove also provided us with information on the time on the market for most properties, as well as rental data for about $29,000$ flats that were listed in London in 2011 and 2012, which allows us to compare rental prices across leasehold and freehold properties.

[3]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.

2.2 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 (apartments) are mainly traded as leaseholds. Since the market for flats and the market for houses are relatively segmented and 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 house 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 at the time of transaction, 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.

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. Overall, flats have significant variation across contract types (freehold vs. leasehold), within leaseholds (by number of years remaining), and across geographic areas.[4]

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 these observable characteristics across leaseholds with different remaining lease length (which will be our main source of price variation); there are some small differences between freeholds and leaseholds, as documented in Appendix Figure A.27.

[4]For each of the 2,375 3-digit 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. To visualize the geographic variation of freeholds and leaseholds, Appendix Figures A.3 - A.26 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.

2.3 Price Variation by Lease Length Remaining in the U.K.

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

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

We control for average prices in a property's geography by including 3-digit postcode (ξ_h) by time of sale (ψ_t) 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.[5] 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 including the quarter of sale, and in column (3) by including 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 leaseholds with maturities of more than 700 years trade at approximately the same price: the coefficient on β_{700+} is small and statistically indistinguishable from zero. This suggest that the present value of rents starting in 700 years is

[5]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.

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. The results are robust to the various specifications reported in Table 2.

To our knowledge, this is the first extensive analysis of the relative valuation of leaseholds and freeholds using the universe of transactions and lease terms in England and Wales, combined with an extensive set of hedonic characteristics for the properties. The analysis reveals substantial discounts for shorter leaseholds compared to longer leaseholds and to freeholds. Interestingly, when informally investigating the priors of participants in this market (home buyers, valuers, estate agents) we found them to be very dispersed. In particular, a number of valuers believe the discounts to be smaller than those we found in our systematic analysis, while a number of homebuyers believe them to be bigger. As discussed in Appendix A.1.5, the priors appear to be based on either little data, introspection, or exponential discounting at some conventional rate.[6] This dispersion is consistent with significant heterogeneity of properties, segmentation of the housing market, and the absence of a large-scale systematic empirical analysis of buyers' valuations. In Section 3, we show that our estimated price differences are not driven by a number of frictions that could differentially affect the flow utility between leaseholds of different maturity and freeholds. Instead, the price differences suggest a significant present value attached by buyers to rents 100 or more years in the future, and, therefore, a relatively low discount rate over those horizons.

2.4 Singapore Residential Housing Data

We 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 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 3 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 transactions each year are of freehold properties. We observe substantial dispersion in the lease length remaining at the time of sale. Figure 2 plots the remaining lease length at sale for leaseholds with initially 99 years (left panel) and initially 999 years

[6] Valuers at most look at about 200 transactions scattered over a number of years, 10 or more, and often use subjective judgment and exponential discounting to fill in gaps in the valuations.

(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. Conditional on our geographic and time 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 (see Appendix Figure A.28).

2.5 Price Variation by Lease Length Remaining in Singapore

To analyze the relative price paid for leaseholds and freeholds we run regression (2) below. The unit of observation is a property i of type g (e.g., apartment, condominium, detached house, executive condominium, semi-detached house and terrace house), of title type s (either "strata" or "land"),[7] in geography h, 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 five 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.

$$\ln(Price)_{i,h,s,g,t} = \alpha + \sum_{j=1}^{6} \beta_j \mathbf{1}_{\{T_{i,t} \in MaturityGroup_j\}} + \gamma Controls_{i,t} + \\ + \xi_h \times \rho_s \times \phi_g \times \psi_t + \epsilon_{i,h,s,g,t} \tag{2}$$

The results from this regression are shown in Table 4. In column (1) we control for 5-digit postcode (ξ_h) by title type (ρ_s) by property type (ϕ_g) by transaction quarter (ψ_t) 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 discount to otherwise identical freeholds. For example, a lease with 96-100 years remaining

[7] 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. See Appendix A.2 for details.

maturity trades at an 11.8% discount, a lease with 71-85 years remaining maturity trades at a 24% discount.[8] In column (2) we control for the transaction month rather than the transaction quarter. 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 age of the property 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.

3 Frictions and Leasehold Discounts

In Section 2 we estimated significant price differences between 100 year leaseholds and otherwise similar freeholds or leaseholds with longer maturity. In Sections 5 and 6 we will argue that these leasehold discounts are informative about very long-run discount rates. Before discussing the interpretation of our results in terms of discount rates, however, we explore several ex-ante plausible alternative interpretations of the estimated price discounts, all of which involve the flow utility being different across the different contracts: (i) the presence of unobserved structural heterogeneity in the properties sold, (ii) the impact of leasehold covenants, (iii) differential liquidity of leasehold and freehold properties, (iv) a different clientele for these contracts, (v) financing frictions for short leaseholds, (vi) the impact of taxation, or (vii) hold-up problems at lease extension. Overall, there is no evidence that the flow utility from owning leasehold and freehold properties differs across leaseholds of different maturity and freeholds. In terms of the model in the introduction, we argue that conditional on our observable control variables, D is the same across all properties. This will allow us to interpret the estimated discounts in terms of

[8] 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.

net discount rates $(r - g)$.

3.1 Unobserved Structural Heterogeneity

Even after controlling for all observed differences across properties (such as property size), there potentially remains unobserved structural heterogeneity that could vary systematically by lease length. While an econometrician is unable to observe all characteristics that might affect the flow utility from a property, to the extent that these characteristics affect the relative prices paid for leaseholds and freeholds they should also affect the annual market rents for these properties. Conversely, if our controls correctly capture all fundamental sources of systematic heterogeneity across properties, rents should not differ systematically between freeholds and leaseholds of different maturity.

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 3 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.

In Columns (1) - (3) of Table 5, 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 3 shows the rental discounts graphically. These results provide support to the assumption that our controls are correctly capturing the main heterogeneity across properties. This is consistent with the observation that, conditional on geography, observable characteristics did not very significantly across leasehold maturity (see Appendix Figures A.27 and A.28). Finally, an additional 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.

3.2 Leasehold Covenants or Contract Structure

A second alternative interpretation of the results is that buyers might perceive an intrinsic difference between owning a leasehold and owning a freehold (for example, because of restrictions on leaseholders or pure psychological preference for freehold ownership). To show that this is not the case, we show that the price discounts remain the same when we exclude freeholds and use the longest leaseholds as the excluded category (700+ years).[9]

[9] See Appendix Table A.3 and Figure A.29. We conduct a similar analysis for Singapore, using the 99 year leasehold as excluded category. See Appendix Table A.4 and the bottom panel of Appendix Figure A.29.

This analysis, however, does not yet rule out that covenants or other contract characteristics might be more restrictive only on shorter leases, which could affect the relative valuation of leaseholds of different remaining maturity. Ideally, we would like to estimate the price differences between leaseholds with different remaining maturity at the time of transaction, controlling for the initial lease length, which would capture differential covenants attached to contracts with different initial maturity. In practice, this is complicated by the high degree of collinearity between initial and remaining lease length.[10]

To deal with this collinearity we conduct a number of empirical tests, none of which suggest that our results are explained by covenants that vary systematically with initial lease length. In a first test, we run regression (1) while including fixed effects for the 10 most common initial lease lengths (which represent 92% of all transactions).[11] Table 6 shows the results. The inclusion of these fixed effects does not significantly affect the estimated price discounts. The discount for leaseholds with 80-99 years remaining relative to freeholds drops from about 16% to 13%: a small part of the initial 16% discount is now attributed to the fixed effects for contracts with 99 years initial maturity. In addition, the coefficients on the initial lease-length fixed effects do not systematically vary with contract maturity. Overall, we find no evidence that differential covenants are an important explanation for the estimated discounts.

Since we only observe significant variation in initial lease for the group of transactions with 80-99 years remaining, we analyze this group in more detail in Table 7. Columns (1) and (2) show results from a simple variant of regression (1) where the price discount for this group is allowed to differ between contracts with initial lease length above or below 99 years. Consistent with Table 6 we only find a small difference between the two groups of initial lease length.[12] A different specification, presented in columns 5 and 6, restricts the sample to transactions of leaseholds with 80-99 years remaining, and includes initial lease length fixed effects for the 8 most common initial lease lengths in this window. This avoids having to estimate the level of the price discount, and only looks at the differential prices of different contracts that *all* trade with roughly the same number of

[10] The identification of the initial lease length effects – separate from the effect of the years remaining at the time of transaction – relies on observing transactions with approximately the same number of years remaining (say, 125-150) but very different initial lease length. Unfortunately, for all buckets except 80-99 years, there are very few transactions of contracts with higher initial lease length. For example, only 3% of the properties trading with 125-150 years remaining have an initial lease length of above 150 years.

[11] We include fixed effects for initial lease lengths of 99, 120, 125, 150, 155, 199, 200, 250, 800 and 999 years. Results are robust to also including fixed effects for the 10 next most common initial lease lengths. In addition to the controls in Table 2, we also include an indicator for whether transactions occur as a new contract is started.

[12] Columns 3 and 4 show that, in addition, there is essentially no difference in discounts for leaseholds with 100-124 years remaining between contracts with original lease length below or above 125 (though only 2% of the transactions are in the latter group).

years remaining. There is no systematic pattern in discounts across initial lease lengths.

Overall, the analysis in Tables 6 and 7 suggests that even after controlling, to the extent possible, for the initial lease length, the discounts related to the years remaining on the leasehold are large and significant. In addition, the term structure of leasehold discounts we estimate for Singapore between 50 and 99 years (see Appendix Table A.4) keeps the initial length constant (all are 99 year contracts), and thus cannot be explained by differential initial lease length effects. Two additional pieces of evidence suggest that leasehold covenants are unlikely to have a significant confounding impact on our analysis. First, to the extent that restrictive covenants affect 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. Second, a manual inspection of covenants on 801 leasehold properties with different lease lengths in postcode E16 (East London) suggests that the type of covenants included is independent of lease length (see Appendix A.1.7.1).

3.3 Differential Market Liquidity

Leasehold and freehold properties could potentially be differentially liquid in the resale market, in which case our estimated price differences might capture a liquidity discount that increases as lease length declines. To test whether this hypothesis explains the estimated price discounts, Rightmove provided us with for-sale listing information for 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 (see Appendix Figure A.30 for the distribution), which provides a proxy for the liquidity of the asset (see Piazzesi, Schneider and Stroebel, 2013).

To test whether liquidity differs by duration of the lease, Columns (4) to (6) of Table 5 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 leaseholds 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.

3.4 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, 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 8 presents the results of a variant of regression (1) using each individual characteristic as a dependent variable. The coefficients on the leasehold indicator then represent the average difference in each characteristic between leaseholders and freeholders, controlling for property type by region fixed effects (columns 4 and 5) and property characteristics (column 5).[13] 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 is 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.

3.5 Financing Frictions

Financing frictions have the potential to affect the relative valuation of leaseholds and freeholds. 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. This credit constraint makes shorter leaseholds more desirable, *increasing* their valuation relative to a frictionless benchmark.

On the other hand, 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). 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 estimated discounts for leaseholds with maturities around 80 years. However, in Appendix A.4.1 we calibrate a version of the simple valuation

[13] Geographic controls here are more coarse than in previous sections because the Survey of English Housing only reports 354 unique local authority codes. Property controls are those observed in both the SEH and the transaction dataset, such as the number of rooms and the property age.

model from the introduction to show that even under extreme assumptions for the collateral value of the house, financing frictions cannot explain discounts for leases of long maturities. Intuitively, a lease with 200 years remaining will only incur direct losses to its collateral value in 140 years, 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.

3.6 Taxation and the Stamp Duty

Purchases of property in the U.K. are subject to a transaction tax (stamp duty). The tax applies equally to freehold or leasehold purchases. The tax schedule is progressive: for example, a purchase of a property up to £125,000 is tax exempt, while a purchase of a property between £125,001 and £250,000 is taxed at 1% of the *total* purchase price (see Appendix A.1.3). This tax schedule potentially makes shorter term leases more attractive because for similar properties a shorter, and thus cheaper, leasehold might avoid incurring the higher tax bracket. This would bias against finding significant leasehold discounts; however, only buyers of properties that are very close to the boundaries of the tax bracket would be affected, and since the brackets are relatively large the effect on the average discount is unlikely to be quantitatively important.

3.7 Hold-Up at Lease Extension

One friction that might contribute to explaining our results relates to hold-up problems during lease extensions, whereby a freeholder might charge unreasonably high premia and administrative expenses for the purchase of extra years on the lease. These concerns could potentially make leasehold contracts less attractive and therefore contribute to explaining the leasehold price discounts that we estimate in the data.

In recent years, however, U.K. legislation and court practice have systematically alleviated this concern. 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 statutory right to seek a lease extension by 90 years in return for paying a premium (see Appendix A.1.5). If a reasonable premium cannot be negotiated with the freeholder, the leaseholder can refer the matter to tribunals that will establish the payable premium. Badarinza 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 and subject to legal and advisory costs that can run in the "tens of thousands of pounds" (Westminster City Council, 2013), they alleviate the concern that our discounts could simply be due to the hold-up problem.[14]

4 Housing Risk and Returns, and Rent Growth Rates

As discussed in the introduction, interpreting the price discounts estimated in the previous sections 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 9 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 for the period considered are in the range $8-10\%$ for all three countries. 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 Nieuwerburgh (2010), who find a real return of 9-10% before depreciation and property taxes. The bottom panel of Table 9 shows that average real rental growth rates are approximately 0.5% in all three countries. To be conservative, we choose a baseline 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.

[14]The possibility of favorable tribunal decisions, and potentially cheaper extensions outside the court system as an indirect effect, would increase the ex-ante valuation of leaseholds if prospective buyers were to anticipate lower future costs of extensions. To the extent that buyers take this 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: transaction costs related to the extension process can be significant, bargaining times are long (6-18 months), 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.1.5 for more details.

[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 real house price growth and real rent growth over long periods of time are 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 still relatively small despite focusing on samples and countries that are often regarded as having experienced major growth in house prices. Over longer horizons, we expect capital gains to be smaller than those estimated in this sample. Even though this does not necessarily imply lower total returns (since lower price growth also produces higher rental yields), our preferred calibration chooses a conservatively low value for r. For more evidence on low average real house price appreciation and low real rent growth rates see Appendix A.3.3.

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 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 20 countries for the period 1870-2013 and on our own dataset of historical house price indices for these countries.[17] 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 and Ursua (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.[18]

We also investigate the average correlation between consumption and house prices over the entire sample rather than just during crisis periods. Table 10 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 20 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.[19]

While we analyze the risk characteristics of properties, which consist of both the structure and the land, there is evidence that land prices are, if anything, more volatile than the prices of structures. For example, Davis and Heathcote (2007) estimate that swings in

[17] Appendix A.3.3 provides details and sources for the crises dates and the house price series. 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 20 countries for 44 crises and 16 rare disasters occurring in the period 1870-2013.

[18] In Appendix A.3.4 we show that this pattern of house price decline during crises is also observed for the U.K. and Singapore, and provide further evidence that house prices collapse during crises and wars.

[19] Appendix A.3.4 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.

residential land prices accounted for most of the variation in house prices over 1975-2006 for the U.S. (see also Bostic, Longhofer and Redfearn, 2007; Davis and Palumbo, 2008; Nichols, Oliner and Mulhall, 2013). If one conjectures that the claim to the freehold in the very long-run is primarily a claim to the land, this evidence suggests that this claim would be even more risky than the composite of land and structure analyzed here.

Despite extensive efforts to collect a comprehensive 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.[20] 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.

5 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 4. 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 rent growth 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.

[20] 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 incorporate the physical loss of part of the asset.

5.1 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: $E_t[D_{t+s}] = D_t e^{gs}$.[21] In this model, a claim to the rents for T periods, the T-maturity leasehold, is valued at:

$$P_t^T = \int_t^{t+T} e^{-r(s-t)} D_t e^{g(s-t)} ds = \frac{D_t}{r-g}(1 - e^{-(r-g)T}). \tag{3}$$

Correspondingly, the infinite maturity claim, the freehold, is valued at: $P_t = \lim_{T\to\infty} P_t^T = \frac{D_t}{r-g}$. The price discount for a T-maturity leasehold with respect to the freehold is:

$$Disc_t^T \equiv \frac{P_t^T}{P_t} - 1 = -e^{-(r-g)T}. \tag{4}$$

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 magnitude 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 a net 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 $g = 2\%$,[22] and a "low expected

[21] 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.

[22] Rents are unlikely to grow at a faster rate than consumption in the long run, since this would imply

returns" scenario with $r = 5.5\%$, significantly less than our lowest estimate. Figure 5 shows that the discounts increase only 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 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 price discounts for long-dated leaseholds relative to freeholds.

5.2 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 expected 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:

$$Disc^T = -\frac{E_t[P_T]/P_t}{R_{t,t+T}} = -\frac{E_t[P_T]/P_t}{R^f_{t,t+T} + RP_{t,t+T}}, \tag{5}$$

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 of 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

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, 2013). 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, n.d.). 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.

discount factor, since this attaches higher present value to future rents.[23]

To interpret Equation (5), 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 4 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%.[24] This latter estimate should be interpreted with caution not only because of liquidity concerns but also because the period is dominated by the global financial crisis and the European sovereign debt crisis.[25] 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%.[26] Using a calibrated value of 1.4% across the term structure of risk-free discount rates, we can 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 in the long run grow 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 on the rent process we cannot divide the risk premium, $RP_{t,t+T}$, into components that capture the asset-specific quantity and the economy-wide price of long-run risk. However, since rents and consumption are likely to be cointegrated in the long run, claims to long-run rents should be as risky as claims to long-run consumption. For example, Jeske, Krueger and Mitman (2011) show that the share of consumption expenditures on housing in total consumption in the U.S has been remarkably constant at 14.1% over the past 40 years.[27] Long-run rents in cities such as

[23]Notice that we can recover the discounts implied by the Gordon growth model in equation (4) by substituting the model's assumptions in equation (5): $R^f_{t,t+T} + RP_{t,t+T} = e^{-rT}; \quad E_t[P_T]/P_t = e^{gT}$.

[24]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.

[25]Appendix Figure A.37 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.

[26]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.

[27]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

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 4. 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.

6 Implications of the Findings

6.1 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 a 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, and $\kappa > 0$ is the hyperbolic parameter. For $\kappa = 0$ we recover exponential discounting at $e^{-\rho t}$, while for $\rho = 0$ 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.[28] Since we are not aiming to decompose the total discount rate into risk-free and risky subcomponents, we resume our assumption from Section 5.1 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.4.5 derives analytic expressions for the resulting value, as well as for the value of the freehold. The top panels of Figure 6 shows the leasehold 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

adjustment is less likely to affect the stochastic properties (covariance risk) of rents.

[28] 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.

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 term structure of discount rates that 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 the long-run per-period discount rate approaches $\rho = 1.42\%$.

6.2 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-equilibrium 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 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.[29] 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

[29] Appendix A.4.3 discusses each of these models, their calibration, and their implications for our results in more detail.

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.

6.2.1 Directions for Further Research

We now discuss recent avenues of theoretical research that could 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 panels of Figure 6 show 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).[30] 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.[31] 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

[30]See the original reference for model details. In calibrating the model, we aimed 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 not be larger than 12%, the discount rates estimated for dividend strips by Binsbergen, Brandt and Koijen (2012). The calibration of the model that gets closest to achieving all three objectives uses an average log rent growth g of 0.3% per year, a volatility of rents of 0.04 per quarter and a persistence of rents 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.

[31]For a related empirical estimation of consumption dynamics in a large panel of countries see Nakamura, Sergeyev and Steinsson (2012).

(2003) consider the possibility that agents attach higher subjective discounts to short-term cash flows than they do to long-term ones. While this approach has had widespread success in describing individual behavior in disaggregated environments, it has proven difficult at the macroeconomic level due to problems of time inconsistency as well as the countervailing equilibrium consequences that generate flat term structures of discount rates even in the presence of agents with hyperbolic time preference (Barro, 1999; Luttmer and Mariotti, 2003). Therefore, 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 6.1 can be designed. 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.

6.3 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 literature on the economics of climate change, starting with Nordhaus (1973), has focused on the importance of discounting for evaluating the tradeoff between the immediate costs of climate change mitigation policy and its uncertain benefits that occur very far in the future.[32] An empirical literature has tried to infer the appropriate discount rates from the realized returns of traded assets such as private capital, equity, bonds, and real estate. For example, the dynamic integrated climate-economy (DICE) model of Nordhaus and Boyer (2000) and Nordhaus (2008) features a constant rate of discounting, calibrated to 4% to reflect the authors' preferred estimate of the average return to capital.[33]

In this section we discuss the implications of our findings for evaluating very long-run investments in climate change mitigation. The appropriate inference from our estimates about the relevant discount rate depends both on the horizon of the investment and on the relative risk properties of housing compared to investments in climate change mitigation.

The horizon of the investment matters because estimates of expected returns of assets capture only their average return, which might not reveal the appropriate discount rates

[32] See also: Arrow et al. (1996); Weitzman (1998); Groom et al. (2005); Gollier (2006); Nordhaus (2007); Weitzman (2007); Pindyck (2013).

[33] 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.

for long-run claims. For example, our estimates in Table 9 suggest that the average returns to residential housing are above 8%, and even our conservative estimate assumed a rate of return of 6.5%. However, the relevant estimates to evaluate climate policy are the discount rates for cash-flows very far into the future. We found such discount rates to be much lower than those implied by average returns and of the order of 2.6% for 100-year claims on housing.[34]

As Barro (2013) points out, the relative risk properties of climate change investments are important, in particular when the price of long-run risk is high. In such an environment, investments in climate change abatement are desirable if they hedge the risk of bad climatic outcomes, in which case they carry a negative risk premium $RP_{t,t+T} < 0$, but less attractive if such investments are risky. There is an open debate over the risk characteristics of investments in climate change abatement.

Some researchers put forward that the costs of climate change depend positively on economic growth because CO_2 emissions 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 (2012) simulates the DICE model of Nordhaus (2008) and Nordhaus and Boyer (2000) and finds a $\beta > 1$ for investments in climate change abatement technology.[35]

Other researchers point 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. Weitzman (2012) builds a 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 low. In this environment the associated term structure of risk premia is downward sloping because riskiness of the investment declines with the horizon.

Our empirical results provide a broader message of a downward sloping term structure of discount rates not just for long-run hedges but also for long-run risky assets. Since our estimates of long-run discount rates suggest that the long-run price of risk is low, the desirability of investments in climate change abatement is less sensitive to their risk properties. This is reassuring given the reasonable disagreement over the risk properties

[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.

[35] 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.

of climate change discussed above. Our results suggest that agents have a high willingness to invest in climate change abatement investments that reduce *for sure* the future cost of climate change because we find low long-run yields for risk-free cash flows. On the other had, compared to environments with high long-run prices of risk, our results also suggest that investments that only reduce the *risk* of adverse future climatic events are less attractive.

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. Finally, the institutional context we present in this paper lends itself to a direct test for the existence of infinitely-lived rational bubbles, which we pursue in a related paper (Giglio, Maggiori and Stroebel, 2014).

References

Ai, Hengjie, Mariano M. Croce, Anthony M. Diercks, and Kai Li. 2012. "Production-Based Term Structure of Equity Returns." *Social Science Research Network Working Paper Series*.

Alvarez, Fernando, and Urban J. Jermann. 2005. "Using Asset Prices to Measure the Persistence of the Marginal Utility of Wealth." *Econometrica*, 73(6): 1977–2016.

Arrow, K. J., W. Cline, K. G. Maler, M. Munasinghe, R. Squitieri, and J. Stiglitz. 1996. *Intertemporal Equity, Discounting, and Economic Efficiency, in "Climate Change 1995: Economic and Social Dimensions of Climate Change"*. Cambridge University Press.

Badarinza, Cristian, and Tarun Ramadorai. 2014. "Long-Run Discounting: Evidence from the UK Leasehold Valuation Tribunal." *Social Science Research Network Working Paper Series*.

Bansal, Ravi, and Amir Yaron. 2004. "Risks for the long run: A potential resolution of asset pricing puzzles." *Journal of Finance*, 59(4): 1481–1509.

Barro, Robert J. 1999. "Ramsey meets Laibson in the neoclassical growth model." *Quarterly Journal of Economics*, 114(4): 1125–1152.

Barro, Robert J. 2006. "Rare disasters and asset markets in the twentieth century." *Quarterly Journal of Economics*, 121(3): 823–866.

Barro, Robert J. 2013. "Environmental Protection, Rare Disasters, and Discount Rates." National Bureau of Economic Research Working Paper 19258.

Barro, Robert J., and Jose F. Ursua. 2008. "Macroeconomic Crises since 1870." *Brookings Papers on Economic Activity*, 39(1 (Spring): 255–350.

Belo, Frederico, Pierre Collin-Dufresne, and Robert S. Goldstein. 2012. "Endogenous Dividend Dynamics and the Term Structure of Dividend Strips." National Bureau of Economic Research Working Paper 18450.

Binsbergen, Jules van, Michael Brandt, and Ralph Koijen. 2012. "On the Timing and Pricing of Dividends." *American Economic Review*, 102(4): 1596–1618.

Binsbergen, Jules van, Wouter Hueskes, Ralph Koijen, and Evert Vrugt. 2013. "Equity yields." *Journal of Financial Economics*, 110(3): 503 – 519.

Boguth, Oliver, Murray Carlson, Adlai J. Fisher, and Mikhail Simutin. 2011. "Leverage and the Limits of Arbitrage Pricing: Implications for Dividend Strips and the Term Structure of Equity Risk Premia." *Social Science Research Network Working Paper Series*.

Bordo, Michael, Barry Eichengreen, Daniela Klingebiel, and Maria Soledad Martinez-Peria. 2001. "Is the crisis problem growing more severe?" *Economic policy*, 16(32): 51–82.

Bostic, Raphael W., Stanley D. Longhofer, and Christian L Redfearn. 2007. "Land leverage: decomposing home price dynamics." *Real Estate Economics*, 35(2): 183–208.

Burn, Edward Hector, John Cartwright, and Geoffrey C. Cheshire. 2011. *Cheshire and Burn's Modern Law of Real Property.* Oxford University Press.

Campbell, John Y., and John H. Cochrane. 1999. "By Force of Habit: A Consumption Based Explanation of Aggregate Stock Market Behavior." *Journal of Political Economy*, 107(2): 205–251.

Cochrane, John H. 2011. "Presidential address: Discount rates." *Journal of Finance*, 66(4): 1047–1108.

Council of Mortgage Lenders. 2013. "What minimum unexpired lease term does the lender accept?" *CLM Lender's Handbook*.

Davis, Morris A., and Jonathan Heathcote. 2007. "The price and quantity of residential land in the United States." *Journal of Monetary Economics*, 54(8): 2595–2620.

Davis, Morris A., and Michael G. Palumbo. 2008. "The price of residential land in large US cities." *Journal of Urban Economics*, 63(1): 352–384.

Eisenbach, Thomas M., and Martin C. Schmalz. 2013. "Up close it feels dangerous: 'anxiety' in the face of risk." Federal Reserve Bank of New York Staff Reports 610.

Favilukis, Jack, Sydney C. Ludvigson, and Stijn Van Nieuwerburgh. 2010. "The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk-Sharing in General Equilibrium." National Bureau of Economic Research Working Paper 15988.

Flavin, Marjorie, and Takashi Yamashita. 2002. "Owner-occupied housing and the composition of the household portfolio." *American Economic Review*, 92(1): 345–362.

Gabaix, Xavier. 2012. "Variable rare disasters: An exactly solved framework for ten puzzles in macro-finance." *Quarterly Journal of Economics*, 127(2): 645–700.

Giglio, Stefano, Matteo Maggiori, and Johannes Stroebel. 2014. "No-Bubble Condition: Model-Free Tests in Housing Markets." *Unpublished Manuscript New York University, and University of Chicago*.

Gollier, Christian. 2006. "An Evaluation of Stern's Report on the Economics of Climate Change." Institut d'Économie Industrielle (IDEI), Toulouse IDEI Working Papers 464.

Gollier, Christian. 2012. "Evaluation of long-dated investments under uncertain growth trend, volatility and catastrophes." Toulouse School of Economics (TSE) TSE Working Papers 12-361.

Gordon, Myron J. 1982. *The investment, financing, and valuation of the corporation.* Greenwood Press.

Groom, Ben, Cameron Hepburn, Phoebe Koundouri, and David Pearce. 2005. "Declining discount rates: the long and the short of it." *Environmental and Resource Economics*, 32(4): 445–493.

Gyourko, Joseph, and Donald B. Keim. 1992. "What does the stock market tell us about real estate returns?" *Real Estate Economics*, 20(3): 457–485.

Gyourko, Joseph, Christopher Mayer, and Todd Sinai. 2013. "Superstar Cities." *American Economic Journal: Economic Policy*, 5(4): 167–99.

Jeske, Karsten, Dirk Krueger, and Kurt Mitman. 2011. "Housing and the Macroeconomy: The Role of Bailout Guarantees for Government Sponsored Enterprises." National Bureau of Economic Research Working Paper 17537.

Laibson, David. 1997. "Golden eggs and hyperbolic discounting." *Quarterly Journal of Economics*, 112(2): 443–478.

Leigh, Wilhelmina A. 1980. "Economic depreciation of the residential housing stock of the United States, 1950-1970." *Review of Economics and Statistics*, 62(2): 200–206.

Lettau, Martin, and Jessica A. Wachter. 2007. "Why Is Long-Horizon Equity Less Risky? A Duration-Based Explanation of the Value Premium." *Journal of Finance*, 62(1): 55–92.

Lustig, Hanno N., and Stijn Van Nieuwerburgh. 2005. "Housing collateral, consumption insurance, and risk premia: An empirical perspective." *Journal of Finance*, 60(3): 1167–1219.

Luttmer, Erzo G., and Thomas Mariotti. 2003. "Subjective discounting in an exchange economy." *Journal of Political Economy*, 111(5): 959–989.

Nakamura, Emi, Dmitriy Sergeyev, and Jon Steinsson. 2012. "Growth-rate and uncertainty shocks in consumption: Cross-country evidence." National Bureau of Economic Research.

Nakamura, Emi, Jón Steinsson, Robert Barro, and José Ursúa. 2013. "Crises and Recoveries in an Empirical Model of Consumption Disasters." *American Economic Journal: Macroeconomics*, 5(3): 35–74.

Nichols, Joseph B., Stephen D. Oliner, and Michael R. Mulhall. 2013. "Swings in commercial and residential land prices in the United States." *Journal of Urban Economics*, 73(1): 57–76.

Nordhaus, William D. 1973. "The Allocation of Energy Resources." *Brookings Papers on Economic Activity*, 4(3): 529–576.

Nordhaus, William D. 2007. "A Review of the Stern Review on the Economics of Climate Change." *Journal of Economic Literature*, 45: 686–702.

Nordhaus, William D. 2008. *A question of balance: Weighing the options on global warming policies.* Yale University Press.

Nordhaus, William D. 2013. *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World.* Yale University Press.

Nordhaus, William D., and Joseph Boyer. 2000. *Warming the world: economic models of global warming.* MIT press.

Pástor, Ľuboš, and Pietro Veronesi. n.d..

Petersen, Mitchell A. 2009. "Estimating standard errors in finance panel data sets: Comparing approaches." *Review of Financial Studies*, 22(1): 435.

Piazzesi, Monika, Martin Schneider, and Johannes Stroebel. 2013. "Segmented Housing Search." Working Paper, Stanford University.

Piazzesi, Monika, Martin Schneider, and Selale Tuzel. 2007. "Housing, consumption and asset pricing." *Journal of Financial Economics*, 83(3): 531–569.

Pindyck, Robert. 2013. "Climate Change Policy: What Do the Models Tell Us?" *Journal of Economic Literature*, 51(3): 860–872.

Reinhart, Carmen M., and Kenneth S. Rogoff. 2008. "Is the 2007 US Sub-Prime Financial Crisis so Different? An International Historical Comparison." *American Economic Review: Papers and Proceedings*, 98(2): 339–344.

Reinhart, Carmen M., and Kenneth S. Rogoff. 2009. *This time is different: Eight centuries of financial folly.* Princeton University Press.

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy*, 82(1): 34–55.

Schularick, Moritz, and Alan M. Taylor. 2012. "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 18702008." *American Economic Review*, 102(2): 1029–1061.

Shiller, Robert J. 2006. "Long-Term Perspectives on the Current Boom in Home Prices." *The Economists' Voice*, 3(4): 1–11.

Stern, Nicholas. 2007. "The economics of climate change: the Stern report." *Cambridge, UK.*

Weitzman, Martin L. 1998. "Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate." *Journal of Environmental Economics and Management*, 36(3): 201 – 208.

Weitzman, Martin L. 2001. "Gamma Discounting." *American Economic Review*, 91(1): 260–271.

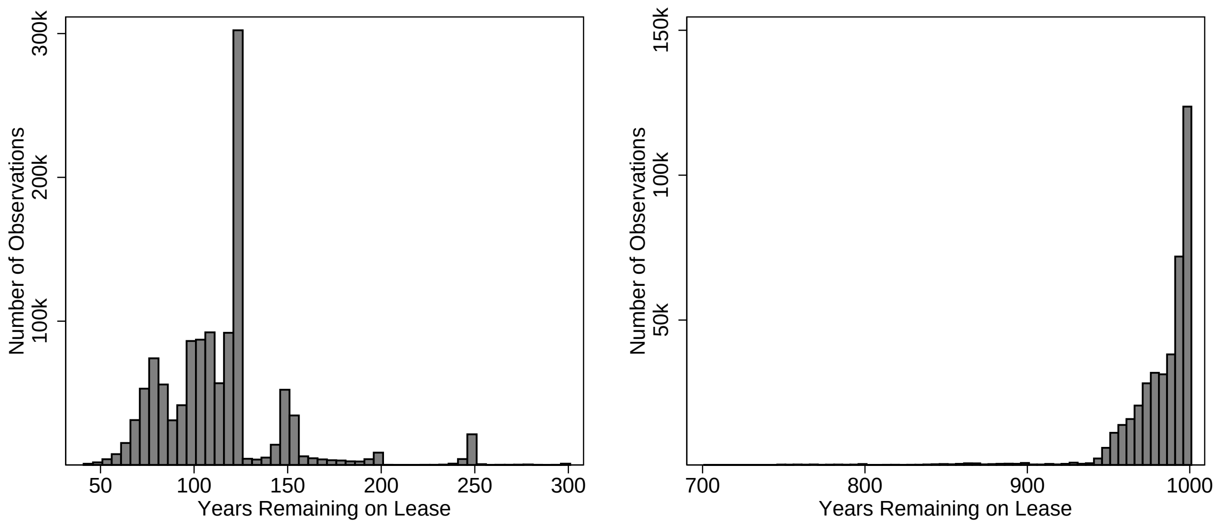
Weitzman, Martin L. 2007. "A Review of the Stern Review on the Economics of Climate Change." *Journal of Economic Literature*, 45(3): 703–724.

Weitzman, Martin L. 2012. "Rare Disasters, Tail-Hedged Investments, and Risk-Adjusted Discount Rates." National Bureau of Economic Research Working Paper 18496.

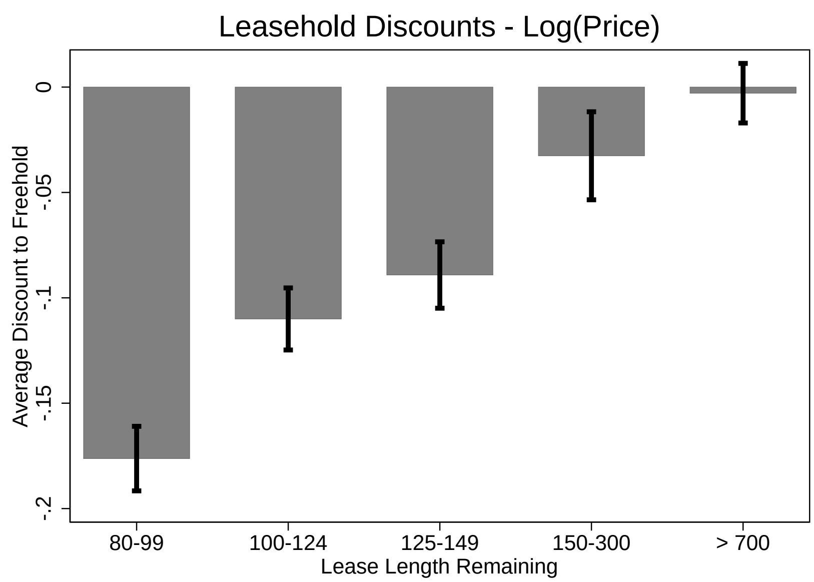
Weitzman, Martin L. 2013. "Tail-Hedge Discounting and the Social Cost of Carbon." *Journal of Economic Literature*, 51(3): 873–882.

Westminster City Council. 2013. "Homing in on the Issues: Perspectives on the housing crisis."

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



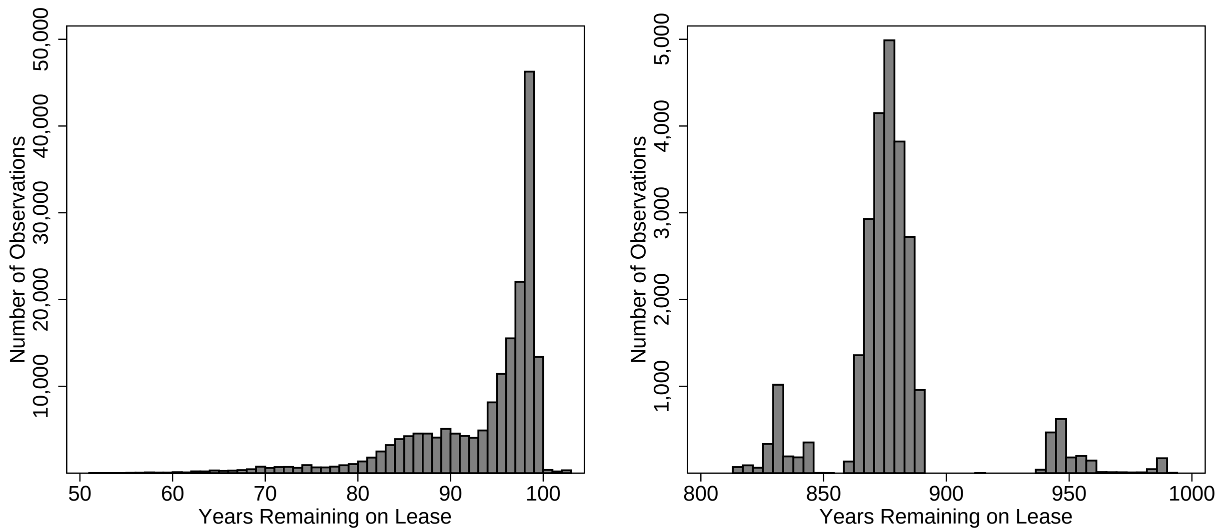
(a) Histogram of Remaining Lease Length



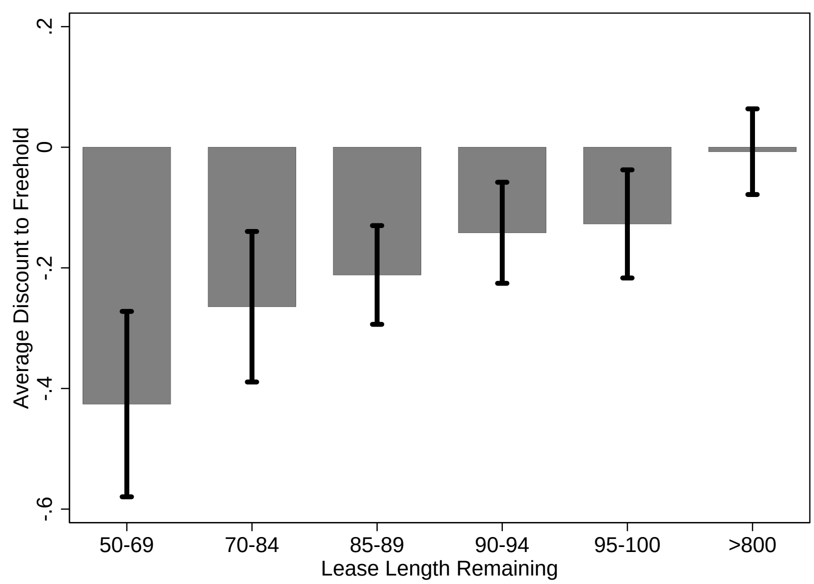
(b) Price Discount by Remaining Lease Length

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. The 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: Singapore Sample and Price Discounts



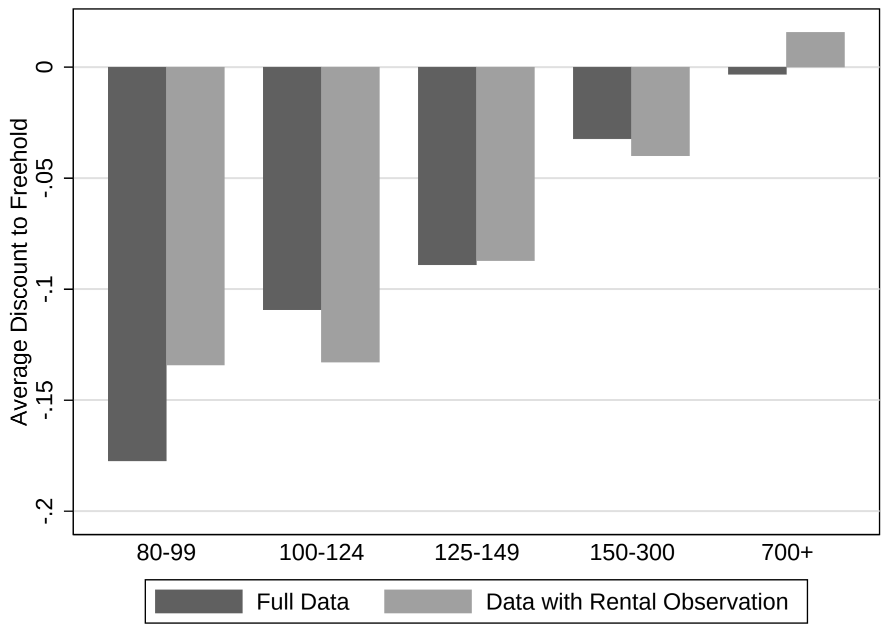
(a) Histogram of Remaining Lease Length



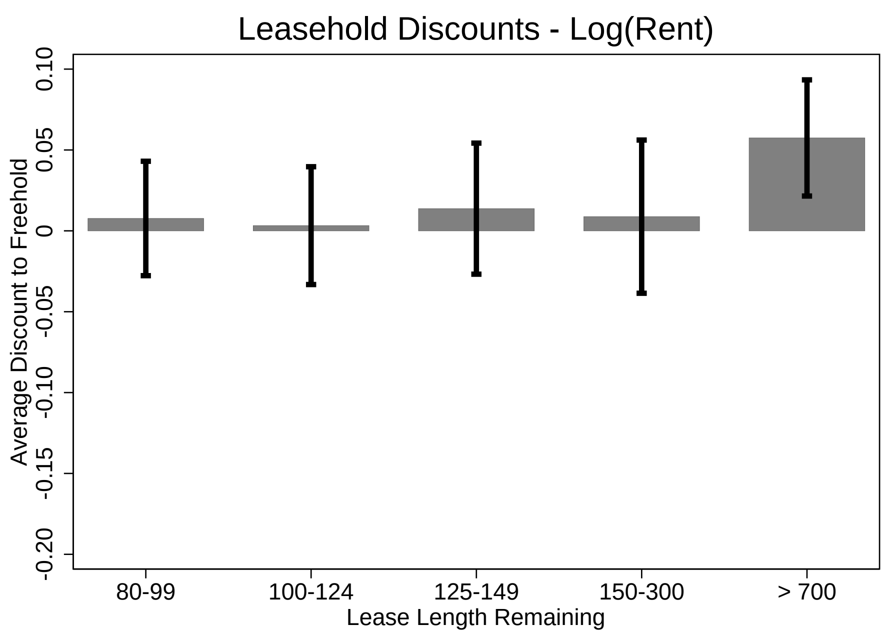
(b) Price Discount by Remaining Lease Length

Note: The 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 (2). 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 4. 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 3: Rental Data Analysis



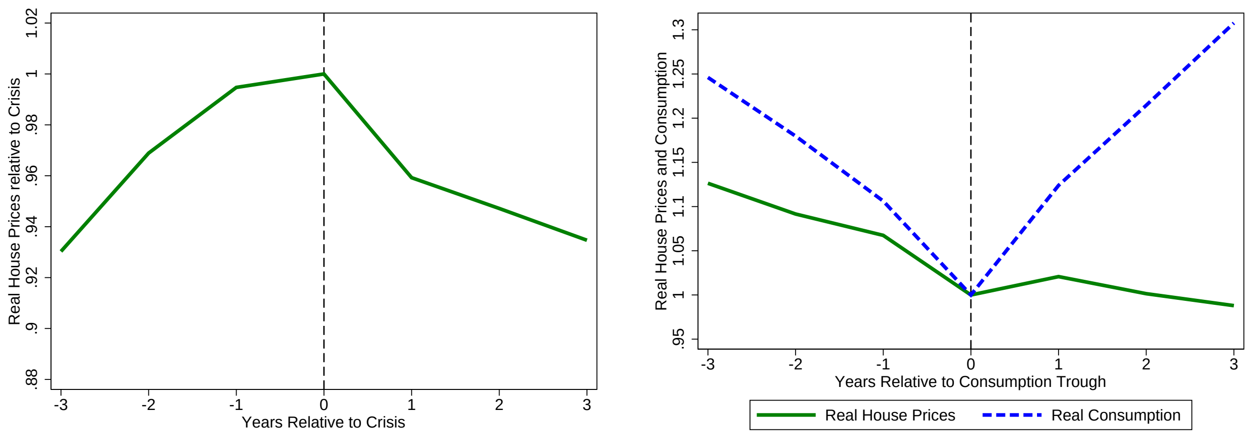
(a) Price Discount by Remaining Lease Length, Properties with Rental Data



(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.

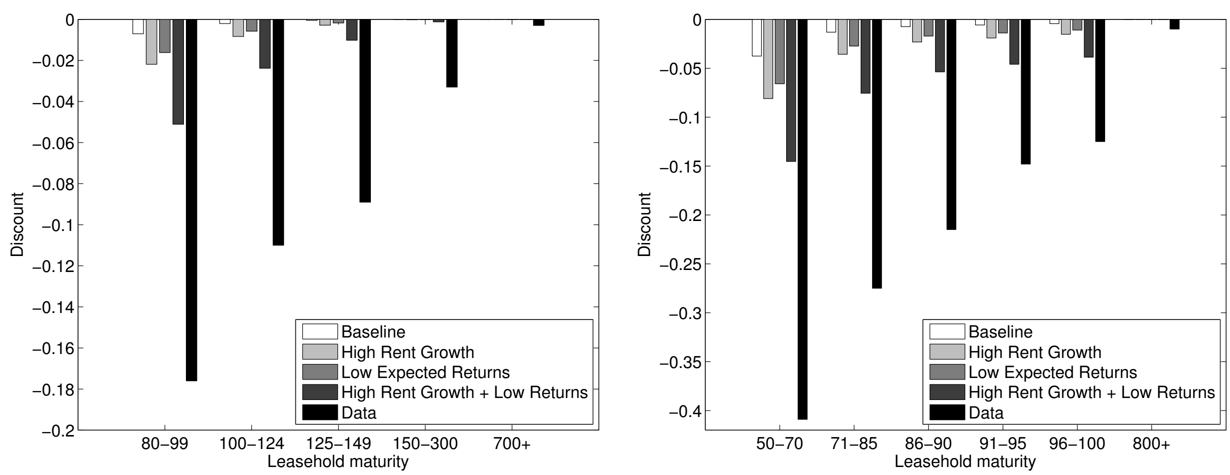
Figure 4: House Price Riskiness



(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 and Ursua (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.

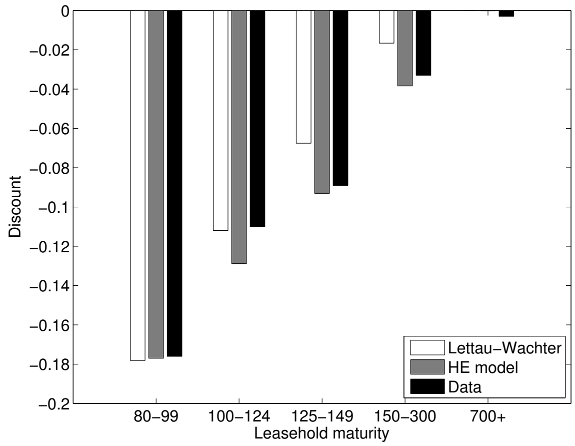
Figure 5: Constant Discount Gordon Growth Model: Model-Implied Discounts vs. Data



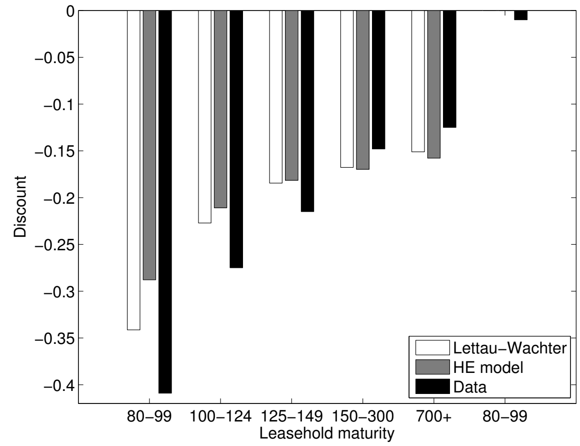
(a) U.K. (b) Singapore

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 $g = 2\%$.

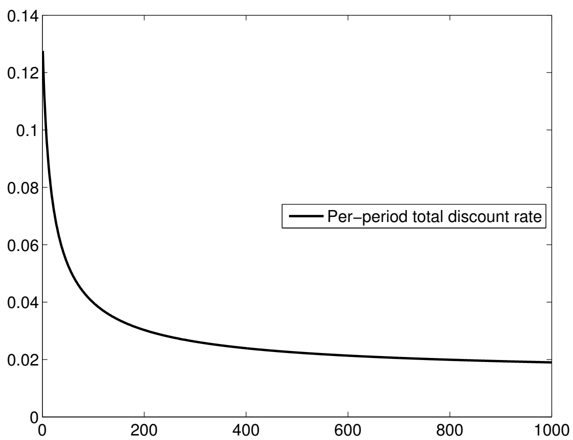
Figure 6: Hyperbolic-Exponential Discounting and Lettau and Wachter (2007)



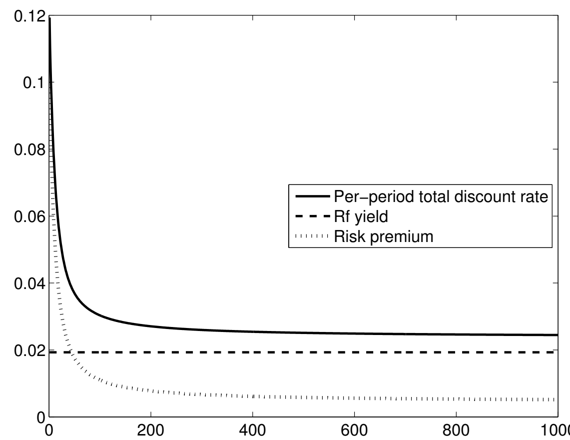
(a) U.K.



(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 discussed in Section 6.1. 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.

Table 1: U.K.: Sample Overview

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

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

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 (N), 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 × M	PC × Q	PC × Y	PC × M	PC × M	PC × M	PC × M
Controls	✓	✓	✓	✓, × 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, 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 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: Singapore: Data Sample

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

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

Table 4: Singapore: Impact of Lease Type on Prices

	(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 (2). To convert into percentage discounts for leasehold properties relative 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 built within the last 3 years of our transaction date; in column (4) we only focus on properties that were bought by a private individual (and not the HDB). 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 5: 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 6: Analysis with contract type fixed effects

	(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 × Y	PC × Q	PC × M	PC × Y	PC × Y	PC × Y
Controls	✓	✓	✓	✓, × 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 7: Initial Lease Length Analysis

	Panel A					Panel B	
	(1)	(2)	(3)	(4)		(5)	(6)
Contract Type					**Initial Lease Length**		
80-99 years, Init. Lease >99	-0.133***	-0.133***	-0.133***	-0.133***	99 Years	-0.065***	-0.067***
	(0.009)	(0.010)	(0.009)	(0.010)		(0.012)	(0.017)
80-99 years, Init. Lease <=99	-0.185***	-0.183***	-0.185***	-0.183***	100 Years	-0.138***	-0.141***
	(0.011)	(0.010)	(0.011)	(0.010)		(0.021)	(0.026)
100-124 years, Init. Lease >125			-0.096***	-0.097***	105 Years	0.025	0.054
			(0.014)	(0.017)		(0.066)	(0.084)
100-124 years, Init. Lease <=125			-0.102***	-0.107***	120 Years	-0.052***	-0.037*
			(0.007)	(0.008)		(0.016)	(0.020)
100-124 years	-0.102***	-0.107***			124 Years	0.013	0.003
	(0.007)	(0.008)				(0.027)	(0.035)
125-149 years	-0.056***	-0.060***	-0.056***	-0.060***	125 Years	-0.036**	-0.041*
	(0.008)	(0.008)	(0.008)	(0.008)		(0.018)	(0.025)
150-300 years	-0.024**	-0.023**	-0.024**	-0.023**	126 Years	-0.074***	-0.088***
	(0.011)	(0.011)	(0.011)	(0.011)		(0.025)	(0.034)
700+ years	0.002	0.004	0.002	0.004	130 Years	-0.025	-0.016
	(0.006)	(0.007)	(0.006)	(0.007)		(0.023)	(0.032)
Fixed Effects	PC × Y	PC × M	PC × Y	PC × M		PC × Y	PC × M
Controls	✓	✓	✓	✓		✓	✓
Restrictions	.	.	.	.		80-100 Years Remaining	
R-squared	0.714	0.731	0.714	0.731		0.772	0.787
N	1,373,383	1,373,383	1,373,383	1,373,383		197,341	197,341

Note: Panel A of the table shows results from regression (1) estimated for flats, where the dummies for buckets of years remaining are interacted with indicators of the initial lease length of the contract. Columns (1) and (2) interact only the indicator for the group of transactions with 80-99 years remaining with an indicator of whether the initial length of the leasehold transacted was below or above 99 years. Columns 3 and 4 also interact the indicator for the group of transactions with 100-124 years remaining with an indicator of whether the contract had initial lease length above or below 125 years. Panel B runs the same hedonic regression restricted to leaseholds that transact with 80-99 years remaining, and incldues fixed effects for the 8 most common initial lease lengths. In all regressions, we include 3-digit postcode by transaction time fixed effects. In columns (1), (3), (5) the transaction time is the transaction year, and in the other columns the transaction month. 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 8: 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 and the number of rooms (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 9: 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 10: 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 and Ursua (2008). Column (1) shows the sample considered. Columns (2) and (3) show the mean and standard deviation of real house price growth. Columns (4) and (5) show the mean and standard deviation of real consumption growth. Column (6) shows the correlation of real house price growth and real consumption growth.