

Very Long-Run Discount Rates: Executive Summary

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Long-run discount rates play a central role in economics and public policy. 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. 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."

In this paper 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 residen-

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tial 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.

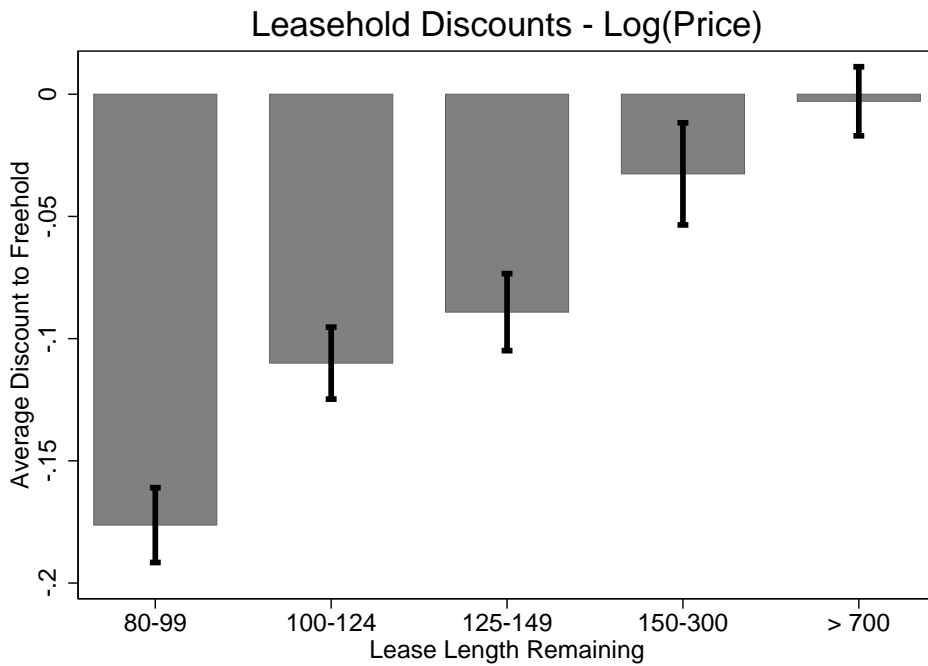


Figure 1: Estimated leasehold discounts for the U.K.

Figure 1 presents estimates of the log difference in prices between leaseholds with varying remaining years at the time of sale and otherwise identical freeholds, using U.K. data.¹ Leaseholds with 80 to 99 years remaining are valued about 15% less than otherwise identical freeholds; leaseholds with maturity of 100 to 124 years are valued 10% less than freeholds. There are no price differences between leaseholds with maturities of more than 700 years and freeholds.

¹To obtain percentage discounts for a coefficient β , simply compute $e^\beta - 1$.

The discounts we observe on these very long-term (but finite maturity) contracts relative to freeholds are informative about the value that households attach to perpetual rental income starting at leasehold expiry. Therefore, they can be used to infer the agents' discount rates for cash flows that arise hundreds of years from now. However, before interpreting our results in terms of discount rates, we ensure that the leasehold discounts we observe are indeed due to the different maturities of these contracts, and not the result of frictions that may differentially affect leaseholds of different maturities and freeholds. 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.

Having excluded alternative explanations for the observed discounts, we interpret the economic magnitude of the observed leasehold discounts and implied discount rates. Starting with a simple constant-discount-rate model, suppose that 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:

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

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. 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 ex-

pected 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 low long-run risk premium for rents. Since rents are risky, they also imply a low long-run price of risk. We quantify the required discount rate for cash flows that arise more than 100 years from now to about 2.6% per year. This number is much lower than what most general equilibrium asset pricing models would predict, and more generally it can be used as a benchmark for previously untested predictions of asset pricing models.²

Our low estimate for the very long-run discount rates has strong 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

²For example, the long-run risk model of Bansal and Yaron (2004), the habit formation model of Campbell and Cochrane (1999), and the rare disaster model of Barro (2006) and Gabaix (2012) all imply a flat or upward sloping term structure of discount rates for risky cash flows, reaching much higher levels than 2.6% for maturities over 100 years.

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.

Finally, 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.

To conclude, we find that explaining the observed prices of leaseholds and freeholds requires long-run discount rates for risky cash flows such as housing to be below 2.6%. This finding provides a new testing ground for asset pricing models, and has policy implications in all cases when a long-run trade-off is at stake, like intergenerational fiscal policy and climate change intervention policies.

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