Very Long-Run Discount Rates

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Discounting the Very Long Run

• Long-run discount rates play crucial role in many economic questions
  • Climate change: trade-off immediate costs and very distant benefits

• Little direct empirical evidence on very long-run discount rates
  • OMB recommends using wide range of discount rates (1% - 7%) for “intergenerational” projects
  • While markets provide a reference for discounting within a generation, “for extremely long time periods no comparable private rates exist.”

• Empirical Challenge:
  • Would like to observe prices of claims to cash flows at all maturities
  • We generally only observe:
    • Infinite maturity assets: equities
    • Relatively short maturity assets: bonds or dividend strips
Our Approach

- Exploit a feature of housing markets in the UK and Singapore to provide *first direct estimates of very long-run discount rates*

- Residential property ownership:
  - **Freeholds**: Permanent ownership (as in US)
  - **Leaseholds**: Temporary ownership for varying tenure (99 - 999 years)
  - **Key**: Prepaid; Liquid secondary market for leaseholds; similar properties; few contractual restrictions on leaseholders
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\[
\text{Freehold: } P = \frac{D}{r-g}
\]

\[
\text{Leasehold: } P^T = \frac{D}{r-g} \left(1 - e^{-(r-g)T}\right)
\]
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\[ Disc_t^T \equiv \frac{P_t^T}{P_t} - 1 = -e^{-(r-g)T} \]
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\[
Disc_t^{100} \equiv \frac{P_t^{100}}{P_t} - 1 = -e^{-(0.06-0.005)100} = -0.4\%
\]
This paper

- Construct dataset of all freehold and leasehold transactions
- Estimate:
  - Term structure of leasehold discounts using hedonic regressions
  - Average returns to housing (6-8%) and rent growth (0.5%)
- Learn about long-run discount rates (risk free and risk premia)
- Discuss implications for asset pricing, macroeconomics, and environmental economics
Figure 2: Price Discount by Remaining Lease Length (U.K.) – Houses with hedonics

Note: This figure shows $b_j$ coefficients from regression (1). To convert into percentage discounts for leasehold properties of a certain maturity, construct $e^{b_j}$. In the top panel the dependent variable is the log price paid for properties in the U.K. between 2009 and 2013, corresponding to column (3) in Table 2, in the bottom panel it is the log price per room, corresponding to column (6) in Table 2. We only include properties which we could match to property listings with information on the number of bedrooms and bathrooms. We include postal district by property type by transaction month by number of bedrooms fixed effects. We also control for the number of bathrooms and the total number of rooms, as well as whether the property is a new construction. The bars indicate the 95% confidence interval of the estimate using standard errors clustered at the level of the fixed effects.
Results Preview - Average and Long-run Discount Rates

- Jointly, high average return and large discounts for long-term leases:
  - Average return uninformative about long-run discount rates
    - Low long-run discount rates
    - Downward sloping term structure of discount rates
  - Many leading asset pricing models struggle to qualitatively match this.

- If long-run housing is risky:
  - Low long-run risk-free rate
  - Low long-run price of risk
Data for the UK

- Administrative data on all transactions and lease terms since 2009
  - 2 million transactions; 22% leasehold properties.
  - Recently purchased data for 1995+ (18 million transactions)
- Property characteristics from Rightmove.co.uk
- Common initial lease length: 99, 125, 150, 250, 999 years.
Hedonic Regressions: Specification

\[
\log(Price)_{i,h,g,t} = \alpha + \sum_{i \in TenGroup} \beta_i \mathbb{1}_{\{Tenure \in i\}} + \gamma Controls_{i,t} + \\
\xi_h \times \phi_g \times \psi_t + \epsilon_{i,h,g,t}
\]

- **TenGroup** \(_i\): Buckets of *remaining* lease length
- **\(\xi_h\)**: Property Type Fixed Effect (e.g. Apartment, Semi-Detached,...)
- **\(\phi_g\)**: Postcode Fixed Effect
- **\(\psi_t\)**: Time Fixed Effect (Month)
- **Controls**: Age, Number of bedrooms, Property size
Leasehold Discounts - Log(Price)

Average Discount to Freehold

Lease Length Remaining

70-84 85-99 100-124 125-149 150-299 > 700

Note: This figure shows $b_j$ coefficients from regression (1). To convert into percentage discounts for leasehold properties of a certain maturity, construct $e^{b_j}$. In the top panel the dependent variable is the log price paid for properties in the U.K. between 2009 and 2013, corresponding to column (3) in Table 2, in the bottom panel it is the log price per room, corresponding to column (6) in Table 2. We only include properties which we could match to property listings with information on the number of bedrooms and bathrooms. We include postal district by property type by transaction month by number of bedrooms fixed effects. We also control for the number of bathrooms and the total number of rooms, as well as whether the property is a new construction. The bars indicate the 95% confidence interval of the estimate using standard errors clustered at the level of the fixed effects.
Key Take-Aways

• Sizable discounts for relatively long-run leaseholds.

• Slope of the term structure of leasehold discounts suggests discounts related to remaining lease length.

• 700+ year leaseholds priced identically to freeholds.
  • No systematic unobserved structural heterogeneity between leasehold and freehold properties.
  • Discounts not driven by covenants on leaseholders.

• Similar discounts when comparing leaseholds with different maturities.
  • Keeps contract structure constant.

• Very similar leasehold discounts observed in Singapore.
Other explanations

- **Differences in Buyer Characteristics:**
  - Priced by different marginal buyers?
  - Survey of English Housing
  - Conditional on our controls, leasehold owners:
    - Are 1.3 years younger (mean 52.4 years)
    - Have £5.6 higher weekly income (mean £350)
    - Have 0.02 more household members (mean 2.53)

- **Financing Frictions:**
  - Most UK banks require 30 years remaining at term-end
  - Leases with duration 70 years are unaffected
  - For reasonable “collateral values” of housing and conventional discount rates, no impact on leases with > 150 years remaining.
Freehold Properties’ Expected Returns

- **Balance Sheet approach: National Accounts Data**
- **Price/Rent approach: Price series + Initial Baseline**

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>Singapore</th>
<th>United Kingdom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Balance Sheet</td>
<td>Price/Rent</td>
<td>Balance Sheet</td>
</tr>
<tr>
<td>Gross Return</td>
<td>10.3%</td>
<td>10.7%</td>
<td>10.4%</td>
</tr>
<tr>
<td>Rental Yield</td>
<td>8.3%</td>
<td>9.8%</td>
<td>6.1%</td>
</tr>
<tr>
<td>Capital Gain</td>
<td>2.0%</td>
<td>0.8%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Depreciation</td>
<td>1.5%</td>
<td>1.5%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Taxes</td>
<td>0.67%</td>
<td>0.67%</td>
<td>0.5%</td>
</tr>
<tr>
<td><strong>Real Net Return</strong></td>
<td><strong>8.1%</strong></td>
<td><strong>8.5%</strong></td>
<td><strong>8.4%</strong></td>
</tr>
<tr>
<td>Real Rent Gr.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Riskiness of Housing

- High returns consistent with riskiness of housing
- Real house prices fall:
  - After financial crises
  - During consumption disasters and wars
- Positive correlation between house price and consumption growth

(c) 44 Financial Crises in 21 Countries (Reinhart & Rogoff)  
(d) 16 Consumption Disasters in 8 Countries (Barro)
Leading Asset Pricing Models

- **Empirical Results**: High returns and high leasehold discounts
- Deterministic Gordon-Growth model:

\[
Disc_{t}^{100} \equiv \frac{P_{t}^{100}}{P_t} - 1 = -e^{-(0.06-0.005)100} = -0.4\%
\]
Leading Asset Pricing Models

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  \[ Disc_t^{100} \equiv \frac{P_t^{100}}{P_t} - 1 = -e^{-\left(0.06-0.005\right)100} = -0.4\% \]

- Since housing is risky, most GE asset pricing models predict upward sloping or flat term structure of discount rates (van Binsbergen, Brandt, Koijen, 2012):
  - Long-run risk (Bansal and Yaron, 2004)
  - Habits (Campbell and Cochrane, 2005)
  - Rare Disaster (Barro, 2006; Gabaix, 2012)
Reduced-form matching of term-structure

- **Empirical Results:** High returns and high leasehold discounts
- Suggests downward sloping term structure of discount rates:
  - Hyperbolic functional form
  - Reduced-form model of Lettau and Wachter (2011)
**Application: Climate Change**

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)

- Stern Report argued for 0%, Weitzman/Nordhaus/Pindyck higher rate.
- We showed low overall long-run discount rates.
- If long-run housing is risky:
  - Long-run risk-free discount rates are relatively low.
  - Long-run price of risk is relatively low.
- Implications for climate change policy:
  - High willingness to pay to reduce very long-run climate costs for sure.
  - Less willingness to pay to reduce uncertainty about climate outcomes.
Conclusion

- Exploit unique feature of housing markets in the UK and Singapore
- Provide first direct estimate of very long-run discount rates (100+ y)
  - Long-run discount rates are low, much lower than suggested by most asset pricing models.
  - To also match expected returns, need a term structure of discount rates that slopes down in the long-run.
  - Low long-run risk-free rate, and low price of long-run risk.
- Important input for many important questions:
  - Evaluating climate change policy (and other cost-benefit analyses)
  - Long-run implications of fiscal policy
BACKUP SLIDES
Buyer Characteristics

- Segmented Markets? Buyers for different contract types could be different.


- 200,000 observations

\[ \text{Outcome}_i = \alpha + \beta \text{Leasehold}_i + \xi X_i + \phi \text{PropertyType} \times \text{Region} + \varepsilon_i. \]
## Buyer Characteristics

### Table: Characteristics of Buyers of Leaseholds and Freeholds

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

- Harder to mortgage-finance leases with short remaining duration.
- UK: No issues for leaseholds with more than 60-70 years remaining; these are treated like freeholds

<table>
<thead>
<tr>
<th>Mortgage Lender</th>
<th>Leasehold Financing Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Royal Bank of Scotland</td>
<td>Mortgage term plus 30+ years</td>
</tr>
<tr>
<td>Santander</td>
<td>Unexpired lease term 55+ years, 30+ years at mortgage end</td>
</tr>
<tr>
<td>HSBC</td>
<td>Mortgage term plus 25+ years</td>
</tr>
<tr>
<td>Nationwide Building Society</td>
<td>Unexpired lease term 55+ years, 30+ years at mortgage end</td>
</tr>
<tr>
<td>Lloyds TSB</td>
<td>Unexpired lease term 70+ years, 30+ years at mortgage end</td>
</tr>
<tr>
<td>Halifax</td>
<td>Unexpired lease term 70+ years</td>
</tr>
</tbody>
</table>
Financing Frictions

Some elements mitigate financing frictions:

- Right to lease extensions in UK
- If the problem is liquidity, then leaseholds are more attractive

We parametrize reduced-form model of “collateral value of housing”:

\[
P_t^T = \int_t^{t+T} e^{-\rho(s-t)} D_t e^{g(s-t)} (1 - \alpha 1_{\{s > t + T - \bar{T}\}}) ds =
\]

\[
= \frac{D_t}{\rho - g} \left[ 1 - e^{-(\rho - g)T} - \alpha \left( e^{-(\rho - g)(T - \bar{T})} - e^{-(\rho - g)T} \right) \right].
\]

A fraction \( \alpha \) of the rents are lost when the remaining lease length is less than \( \bar{T} \)

Take Away: frictions have essentially no impact on long-maturity leases: e.g. 150-years
<table>
<thead>
<tr>
<th>Country</th>
<th>Real HP Growth Mean</th>
<th>Real HP Growth Std. Dev.</th>
<th>Real PDI Growth Mean</th>
<th>Real PDI Growth Std. Dev.</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>3.20%</td>
<td>6.89%</td>
<td>1.43%</td>
<td>2.77%</td>
<td>0.093</td>
</tr>
<tr>
<td>Belgium</td>
<td>2.80%</td>
<td>5.87%</td>
<td>1.17%</td>
<td>2.27%</td>
<td>0.436</td>
</tr>
<tr>
<td>Canada</td>
<td>2.51%</td>
<td>7.63%</td>
<td>1.37%</td>
<td>2.10%</td>
<td>0.489</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.94%</td>
<td>4.73%</td>
<td>1.12%</td>
<td>1.63%</td>
<td>0.445</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.29%</td>
<td>2.31%</td>
<td>1.27%</td>
<td>1.70%</td>
<td>0.288</td>
</tr>
<tr>
<td>Denmark</td>
<td>1.57%</td>
<td>8.99%</td>
<td>1.09%</td>
<td>2.29%</td>
<td>0.211</td>
</tr>
<tr>
<td>Spain</td>
<td>2.05%</td>
<td>8.26%</td>
<td>0.83%</td>
<td>2.46%</td>
<td>0.631</td>
</tr>
<tr>
<td>Finland</td>
<td>2.04%</td>
<td>8.19%</td>
<td>2.07%</td>
<td>3.21%</td>
<td>0.482</td>
</tr>
<tr>
<td>France</td>
<td>2.52%</td>
<td>5.23%</td>
<td>1.22%</td>
<td>1.58%</td>
<td>0.358</td>
</tr>
<tr>
<td>U.K.</td>
<td>3.53%</td>
<td>8.54%</td>
<td>2.20%</td>
<td>2.74%</td>
<td>0.355</td>
</tr>
<tr>
<td>Ireland</td>
<td>3.70%</td>
<td>9.73%</td>
<td>1.83%</td>
<td>3.59%</td>
<td>0.529</td>
</tr>
<tr>
<td>Italy</td>
<td>0.60%</td>
<td>8.28%</td>
<td>0.82%</td>
<td>2.44%</td>
<td>0.325</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.24%</td>
<td>4.28%</td>
<td>1.55%</td>
<td>1.40%</td>
<td>0.587</td>
</tr>
<tr>
<td>S. Korea</td>
<td>0.59%</td>
<td>7.70%</td>
<td>3.95%</td>
<td>4.58%</td>
<td>0.235</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>3.94%</td>
<td>6.68%</td>
<td>2.84%</td>
<td>3.75%</td>
<td>0.054</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.32%</td>
<td>9.43%</td>
<td>0.48%</td>
<td>3.25%</td>
<td>0.472</td>
</tr>
<tr>
<td>Norway</td>
<td>2.76%</td>
<td>7.23%</td>
<td>2.22%</td>
<td>2.52%</td>
<td>0.064</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2.20%</td>
<td>7.73%</td>
<td>0.98%</td>
<td>3.45%</td>
<td>0.530</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.50%</td>
<td>7.27%</td>
<td>1.34%</td>
<td>2.28%</td>
<td>0.431</td>
</tr>
<tr>
<td>U.S.</td>
<td>1.13%</td>
<td>3.89%</td>
<td>1.60%</td>
<td>1.56%</td>
<td>0.371</td>
</tr>
<tr>
<td>S. Africa</td>
<td>0.88%</td>
<td>9.65%</td>
<td>0.53%</td>
<td>3.05%</td>
<td>0.373</td>
</tr>
</tbody>
</table>
Robustness: cointegration argument

• In the model, the effective discounting for the long run depends on $r - g$.

• What if $g$ becomes really big? (superstar-city effect)

• If prices and rents are cointegrated, in the long run $g$ and capital gains have to grow at the same rate

• If $g$ explodes, $CG$ explodes, and $r - g = CG + DY - g = DY$.

• But real, net $DY$ is always at least 4% -> net price-rent ratio of 25 at the most.

• Still, way too large.
Infinitely-Lived Rational Bubbles


- Rely on failure of the no-bubble condition:
  \[
  \lim_{T \to \infty} E_t[\xi_t, T P_T] \neq 0,
  \]
  For some model-implied SDF \( \xi_t, T \)

- Long literature attempted indirect tests: afflicted by serious econometric problems

- We provide a simple direct test:
  \[
  H_0 : \quad P_t - P_t^T \approx \lim_{T \to \infty} E_t[\xi_t, T P_T] = 0, \quad \text{for large } T.
  \]

- We find no evidence of infinitely-lived rational bubbles even at the peak of the housing-boom (2006-7) in London and Singapore
Rational bubbles: Singapore

Figure 10: Time Series of 999-Year Leases and Freeholds

-0.2 0 0.2 0.4 0.6 0.8
Level relative to Freehold in 1995


Freehold 999-Year Lease

Note: The figure shows the time series of the price level of 999-Year leaseholds and freeholds in Singapore between 1995 and 2013. Estimates are obtained from a regression of log(price/sqft) on 5-digit postcode by property type by title type fixed effects, the same control variables as Table 4 and a separate dummy for each year by lease type (Freehold, 99-Year Lease, 999-Year Lease). All price levels are relative to freeholds in 1995. The bars indicate the 95% confidence interval of the estimate using standard errors clustered at the level of the fixed effect.