Very Long-Run Discount Rates

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Empirical Household Finance PhD Class
**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 *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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![Diagram showing the timeline for freehold and leasehold properties.](attachment:diagram.png)
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\[
\text{Freehold: } P = \frac{D}{r-g}
\]

\[
\text{Leasehold: } P_T^T = \frac{D}{r-g} (1 - e^{-(r-g)T})
\]
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\[
Discount^T \equiv \frac{P^T}{P} - 1 = -e^{-(r-g)T}
\]
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\[
Disc^{100} = \frac{P^{100}}{P} - 1 = -e^{-(0.065-0.007)100} = -0.3\%
\]
Contribution

- QJE paper:
  - Construct dataset of all freehold and leasehold transactions
  - Estimate long-run discount rates using hedonic regressions

- This paper:
  - Compute average returns to housing (6-8%) and rent growth (0.5%)
  - Estimate the shape of the term structure of discount rates
  - Learn about long-run discount rates (risk free and risk premia)
  - Discuss implications for public and environmental economics
Preview of Results

Leasehold Discounts - Log(Price)

Average Discount to Freehold

Lease Length Remaining

80-99  100-124  125-149  150-300  > 700
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**
    • long-run discount rates
    • **Downward sloping** term structure of discount rates
• Long-run housing is risky:
  • Low long-run risk-free rate
  • Low long-run price of risk
• Implications for climate change
  • High willingness to invest in *sure* projects
  • More tolerance for risk
  • Caveat: systematic risks exposures of housing and climate change
Roadmap

• Empirical Analysis
  • Leasehold Discounts: UK
  • Leasehold Discounts: Singapore
  • Expected Returns and Risk

• Constant-discounts Benchmark

• Implications for Climate Change and Intergenerational Policies
Data for the UK

- Administrative data on all transactions and lease terms since 2004
  - 1.3 million transactions for flats
  - 8% Freeholds; Initial lease length distributed between 99 - 999 years
- Property characteristics, listings and rental data from Rightmove.co.uk
Data for the UK

Geographic Distribution of Flats

(a) 80-100 years leaseholds

(b) 700+ years leaseholds
Hedonic Regressions: Specification

\[ \log(Price)_{i,g,t} = \alpha + \sum_{j \in TenGroup_j} \beta_j \mathbf{1}\{\text{RemainLeaseLength}_i \in j\} + \gamma Controls_{i,t} + \phi_g \times \psi_t + \epsilon_{i,g,t} \]

- **TenGroup\_j**: Buckets of *remaining* lease length
- **\(\phi_g\)**: 3-digit Postcode Fixed Effect
- **\(\psi_t\)**: Time Fixed Effect (Month)
- **Controls**: Age, Number of bedrooms and bathrooms, Property size, Property style, Garage, Heating type

- Standard errors are clustered at the year and postcode level
Hedonic Regressions: UK Results - Flats

Leasehold Discounts - Log(Price)

Average Discount to Freehold

Lease Length Remaining

80-99
100-124
125-149
150-300
> 700
Key Take-Aways

• Sizable discounts for relatively long-run leaseholds.

• Very similar leasehold discounts observed for U.K. houses and in Singapore.

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

  • **Our interpretation:** Related to different duration of cash flows (rents), and therefore informative about very long-run discount rates

  • Address other possible interpretations.
Other explanations

- **Unobservable Differences in Property Characteristics:**
  - 700+ year leaseholds priced identically to freeholds.
Other explanations

- **Unobservable Differences in Property Characteristics**:
  - 700+ year leaseholds priced identically to freeholds.
  - Test whether they rent for the same annual amount

\[
\log (Rent)_{i,g,t} = \alpha + \sum_{j \in \text{TenGroup}_j} \beta_j 1\{\text{RemainLeaseLength}_i \in j\} + \gamma \text{Controls}_{i,t} + \epsilon_{i,g,t}
\]

No unobserved differences in hedonics that vary with lease length
Other explanations

- **Contractual Restrictions on Leaseholders:**
  - Would also show up for 700+ year leaseholds
  - Same result when estimating discounts relative to 300 year leasehold
  - Results hold after controlling for initial lease length

- **Differences in Buyer Characteristics:**
  - Leaseholders and freeholders look the same on observables

- **Liquidity or Financing Frictions:**
  - Similar “time on market” to sell freeholds and leaseholds
  - Leaseholds with $> 70$ years mortgage financed identically to freeholds
  - Marketing identical
Risk and Return of Housing

- Find **high expected real returns** (7%+), low rent growth (0.5%)
- Most of the return comes from dividend yield, not capital gain
- High returns consistent with **riskiness** of housing
  - House prices decline during consumption disaster, banking crises, wars
  - House prices growth and consumption growth are correlated
Interpreting the results

- **Main Empirical Findings:**
  - Significant discount for leaseholds vs. freeholds
  - High average expected returns (above 6.5%), low rent growth (0.7%)
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- Constant-discount-rate model with $r = 6.5\%$, $g = 0.7\%$ won’t work:

$$Disc_{t}^{100} = -e^{-(0.065-0.007)100} = -0.3\%$$

- Models with upward-sloping term structures of risk premia explain the average returns but not the leasehold discounts
Interpreting the results

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\[
Disc_{100}^t = -e^{-(0.065 - 0.007)100} = -0.3\%
\]

• Constant-discount-rate model with \( r = 2.6\% \), \( g = 0.7\% \) explains discounts but not average return:

\[
Disc_{100}^t = -e^{-(0.026 - 0.007)100} = -15\%
\]
Interpreting the results

- **Main Empirical Findings:**
  - Significant discount for leaseholds vs. freeholds
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- Constant-discount-rate model with $r = 6.5\%$, $g = 0.7\%$ won’t work:

  \[ \text{Disc}^1_{100} = -e^{-(0.065 - 0.007)100} = -0.3\% \]

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  \[ \text{Disc}^1_{100} = -e^{-(0.026 - 0.007)100} = -15\% \]

- Models with upward-sloping term structures of risk premia explain the average returns but not the leasehold discounts
Interpreting the Results

- **Bottom line:** need low long-run discount rates (around 2-3%)
- Plus high short-term discount rates to explain high expected returns:
  - Hyperbolic-Exponential reduced-form model: \( \frac{e^{-\rho T}}{1 + kT} \)

(a) Leasehold-Freehold discounts

(b) Per-period discount rates
Interpreting the Results

- **Low long-run total discount rate:**
  - Low long-run risk-free rate
    - Informative for pricing safe investments over long horizon
  - Low long-run risk premium
    - Either long-run rents are very safe (low quantity of long-run risk), or long-run price of risk is low.

- **Riskiness of long-run rents?**
  - Insufficient data to answer conclusively
  - Some evidence that long-run rents are not safe:
    - Long-run cointegration with consumption
    - Major declines during rare disasters

→ Our results also useful to price risky investments over long horizon
The “right” value of an asset weighs payments by “marginal utility” (the SDF $\xi$):

$$P_{t+n}(t) = E[\xi_{t+n}D_{t+n}]$$

Alternatively, given $P$ we can find the corresponding discount rate s.t.:

$$P_{t+n}(t) = \frac{E[D_{t+n}]}{(1 + R_n)^n}$$

Each horizon has its own $\xi_{t+n}$, so it will have its own $R_n$
Discounting: a review

- Now consider a claim to many dividends (e.g. the stock market):

\[ P(t) = E [\xi_{t+1} D_{t+1} + \xi_{t+2} D_{t+2} + \ldots + \xi_{t+n} D_{t+n}] \]

or (it’s a bundle of period-specific claims):

\[ P(t) = E [D_{t+1}] + \frac{E [D_{t+2}]}{(1 + R_2)} + \ldots + \frac{E [D_{t+n}]}{(1 + R_n)^n} \]

- If we know \( P \) we can also find that particular \( R \) s.t.

\[ P(t) = E [D_{t+1}] + \frac{E [D_{t+2}]}{(1 + R)} + \ldots + \frac{E [D_{t+n}]}{(1 + R)^n} \]

where \( R \) is the same for all cash flows. This is the average return.
Discounting: a review

- Important observation: from $P$ I can find $R$. From $R$ I cannot find all the $R_n$ of every period

- For example, I cannot know the correct value of a claim to $D_{t+2}, \ldots, D_{t+n}$

- The average discount rate for a bundle of different maturities cannot be used to discount a different combination of maturities
Discounting: a review

- Our results speak directly to this problem.

- We find the term structure of discount rates (of $R_n$) to be downward sloping.

- The average is high even though the long end is low.

- A project whose cash flows arise in the future should be discounted using the appropriate $R_n$.

- But the average rate of return $R$ is uninformative about $R_n$. 
Risk

- A second crucial point is that for any two securities, fixing the maturity, we have:

\[ R_A > R_B \iff Corr(\xi_{t+n}, D^A_{t+n}) > Corr(\xi_{t+n}, D^B_{t+n}) \]

- The risk premium can be decomposed as:

\[ R_A - R_f = \beta_{A,\xi} \lambda_{xi} \]

where \( \beta \) is the risk exposure and \( \lambda \) is the price per unit of risk.

- How exposed to systematic risks are the housing claim and climate change risk?

- A third point is that if climate change is **risky**, then climate change **reduction** is a **hedge**, so the discount rate applied should be **lower** than \( R^f \).
Discounting Climate Change

- What discount rate for long-run environmental policies?
  - Answer depends crucially on: 1) Climate change $\beta$, 2) Long-run Rf, 3) Long-run Risk price
  - Our study provides evidence for Rf and Risk price
  - Low Rf: people care about the future
  - If climate-change policies are hedges ($\beta < 0$), risk-adjustment (which depends on beta) can push discount rate close to 0
  - However, low long-run risk premium makes the optimal decision less sensitive to the exact choice of $\beta$

- Three main **implications for climate change policy**:
  - Long-run discount rates are the right rates to look at
  - High willingness to pay to reduce very long-run climate costs **for sure**
  - Low discount rates for wide range of climate change $\beta$
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 (< 2.5%), 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 policy questions:
  • Evaluating climate change policy (and other cost-benefit analyses)
  • Long-run implications of fiscal policy
  • Large infrastructure spending, education policy, ...
BACKUP SLIDES
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>Real Net Return</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><strong>0.1%</strong></td>
<td><strong>0.2%</strong></td>
<td><strong>0.7%</strong></td>
</tr>
</tbody>
</table>
Other explanations

- **Hold-up problem for leaseholders at extension:**
  
  - 1993 law: right to extend at "reasonable" price ⇒ Mitigates hold-up
  
  - Leaseholder can resort to court: tribunal favorable to leaseholders
  
  - Court protection makes leaseholds more valuable ⇒ Bias against our findings
  
  - Additional value offset by: transaction costs, long bargaining times, legal fees, legal uncertainty
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>St. Dev. (2)</th>
<th>Unconditional (3)</th>
<th>Leasehold 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 (0.21)</td>
<td>-1.30 (0.20)</td>
</tr>
<tr>
<td>Weekly Income (£)</td>
<td>350.2</td>
<td>450.6</td>
<td>-48.07</td>
<td>-3.01 (4.56)</td>
<td>5.60 (4.45)</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 (0.01)</td>
<td>0.02 (0.01)</td>
</tr>
<tr>
<td>Number of dependent children</td>
<td>0.55</td>
<td>0.94</td>
<td>-0.19</td>
<td>-0.01 (0.01)</td>
<td>0.02 (0.01)</td>
</tr>
<tr>
<td>Head of Household Married</td>
<td>0.64</td>
<td>0.48</td>
<td>-0.21</td>
<td>-0.01 (0.01)</td>
<td>0.01 (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 (0.01)</td>
<td>-0.01 (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 (0.01)</td>
<td>0.02 (0.01)</td>
</tr>
<tr>
<td>Very Satisfied with Neighborhood</td>
<td>0.47</td>
<td>0.50</td>
<td>-0.06</td>
<td>0.00 (0.00)</td>
<td>0.00 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
Singapore Time Series
## Housing is Risky

<table>
<thead>
<tr>
<th>Country</th>
<th>Real HP Growth</th>
<th>Real PDI Growth</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>Australia</td>
<td>3.20%</td>
<td>6.89%</td>
<td>1.43%</td>
</tr>
<tr>
<td>Belgium</td>
<td>2.80%</td>
<td>5.87%</td>
<td>1.17%</td>
</tr>
<tr>
<td>Canada</td>
<td>2.51%</td>
<td>7.63%</td>
<td>1.37%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.94%</td>
<td>4.73%</td>
<td>1.12%</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.29%</td>
<td>2.31%</td>
<td>1.27%</td>
</tr>
<tr>
<td>Denmark</td>
<td>1.57%</td>
<td>8.99%</td>
<td>1.09%</td>
</tr>
<tr>
<td>Spain</td>
<td>2.05%</td>
<td>8.26%</td>
<td>0.83%</td>
</tr>
<tr>
<td>Finland</td>
<td>2.04%</td>
<td>8.19%</td>
<td>2.07%</td>
</tr>
<tr>
<td>France</td>
<td>2.52%</td>
<td>5.23%</td>
<td>1.22%</td>
</tr>
<tr>
<td>U.K.</td>
<td>3.53%</td>
<td>8.54%</td>
<td>2.20%</td>
</tr>
<tr>
<td>Ireland</td>
<td>3.70%</td>
<td>9.73%</td>
<td>1.83%</td>
</tr>
<tr>
<td>Italy</td>
<td>0.60%</td>
<td>8.28%</td>
<td>0.82%</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.24%</td>
<td>4.28%</td>
<td>1.55%</td>
</tr>
<tr>
<td>S. Korea</td>
<td>0.59%</td>
<td>7.70%</td>
<td>3.95%</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>3.94%</td>
<td>6.68%</td>
<td>2.84%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.32%</td>
<td>9.43%</td>
<td>0.48%</td>
</tr>
<tr>
<td>Norway</td>
<td>2.76%</td>
<td>7.23%</td>
<td>2.22%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2.20%</td>
<td>7.73%</td>
<td>0.98%</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.50%</td>
<td>7.27%</td>
<td>1.34%</td>
</tr>
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<td>U.S.</td>
<td>1.13%</td>
<td>3.89%</td>
<td>1.60%</td>
</tr>
<tr>
<td>S. Africa</td>
<td>0.88%</td>
<td>9.65%</td>
<td>0.53%</td>
</tr>
</tbody>
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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% $\rightarrow$ 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:

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

- We find no evidence of infinitely-lived rational bubbles even at the peak of the housing-boom (2006-7) in London and Singapore
**Freehold Properties’ Expected Returns**

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

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<td>Balance Sheet</td>
<td>Price/Rent</td>
<td>Balance Sheet</td>
<td>Price/Rent</td>
<td>Balance Sheet</td>
<td>Price/Rent</td>
</tr>
<tr>
<td>Gross Return</td>
<td>10.3%</td>
<td>10.7%</td>
<td>10.4%</td>
<td>10.3%</td>
<td>12.5%</td>
<td>10.9%</td>
</tr>
<tr>
<td>Rental Yield</td>
<td>8.3%</td>
<td>9.8%</td>
<td>6.1%</td>
<td>6.0%</td>
<td>9.7%</td>
<td>6.9%</td>
</tr>
<tr>
<td>Capital Gain</td>
<td>2.0%</td>
<td>0.8%</td>
<td>4.3%</td>
<td>4.3%</td>
<td>2.8%</td>
<td>4%</td>
</tr>
<tr>
<td>Depreciation</td>
<td>1.5%</td>
<td>1.5%</td>
<td>1.5%</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>
<td>0.5%</td>
<td>0%</td>
<td>0%</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>
<td><strong>8.3%</strong></td>
<td><strong>11%</strong></td>
<td><strong>9.4%</strong></td>
</tr>
</tbody>
</table>

**Real Rent Gr.**

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Sample</td>
<td></td>
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<tr>
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</tr>
</tbody>
</table>

- **United States:** 0.1%
- **Singapore:** 0.2%
- **United Kingdom:** 0.7%

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<table>
<thead>
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<tbody>
<tr>
<td>Sample</td>
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</tbody>
</table>

- **Sample:** 1988-2012

- **1990-2012**

- **1996-2012**
Rational bubbles: Singapore

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

Note: The figure shows the time series of the price level of 999-Year leaseholds and freeholds in Singapore between 1995 and 2013. Estimates are obtained from a regression of log(price/sqft) on 5-digit postcode by property type by title type fixed effects, the same control variables as Table 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.