Comment on “Real Estate Production and Structure Depreciation” by Jiro Yoshida

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Objective of This Paper

Estimate Real Estate Production Function

- Returns to scale & Land-structure substitution

  important for city formation.

Document Empirical Patterns of Property Depreciation Rate

- Economic depreciation: rate of $\downarrow$ in asset value with age
- Large cross-sectional variation

Estimate Structure Depreciation Rate

- Important for structure investment

What This Paper Does

Hedonic Regression of Property Value

- Property value, bldg age, floor area, lot size, distance, etc

Use Theoretical Restrictions to Infer Structural Parameters

- Real estate service production function
  - Returns to scale
  - Elasticity of substitution btw land & structure
- Structure depreciation rate
  - Age profile of structure price **not observable**
  - **Bias Corrections**

Theoretical Model

Property Owner's Problem

$$\max_{S,L} \underbrace{V_{t,u}}_{\text{Property value}} - P_t^{ES} E_u \underbrace{S}_{\text{Structure Qty.}} - P_t^L \underbrace{L}_{\text{Land Qty.}}$$

where

$$V_{t,u} = P_t^H \underbrace{\left(\alpha(E_u S)^{\frac{\theta-1}{\theta}} + (1-\alpha)L^{\frac{\theta-1}{\theta}}\right)^{\frac{\eta\theta}{\theta-1}}}_{\text{Real estate service production function}}$$

- E_u: Effectiveness of structure at age u.
- Structure depreciation rate $\delta_u \equiv \frac{\partial \ln E_u}{\partial u}$.

Theoretical Implications

- $\boldsymbol{s_{t,u} + l_{t,u} = \eta}$
  - $s_{t,u} \equiv \frac{P_t^{ES} E_u S}{V_{t,u}} = \frac{\partial \ln V_{t,u}}{\partial \ln S}$; $l_{t,u} \equiv \frac{P_t^L L}{V_{t,u}} = \frac{\partial \ln V_{t,u}}{\partial \ln L}$
- $\boldsymbol{-\frac{\partial V_{t,u}}{\partial u} = \delta_u s_{t,u}}$
  - $\delta_u \equiv \frac{\partial \ln E_u}{\partial u}$
- $\boldsymbol{\frac{\partial s_{t,u}}{\partial u} = \frac{(1-\theta)\delta_u s_{t,u} l_{t,u}}{\theta\eta} \Rightarrow sgn((1-\theta)\delta_u) = sgn(\frac{\partial s_{t,u}}{\partial u})}$

Estimate $\ln V_{t,u} \Rightarrow$ **Compute** $s_{t,u}$, $l_{t,u} \Rightarrow \eta$, δ_u, $sgn((1-\theta)\delta_u)$.

Hedonic Regression of Property Value

$$\begin{aligned}
\ln V_{ijt} &= a_0 + f(A_i, \ln S_i, \ln L_i, D_i) \\
&+ a_2 \ln S_i + a_3(\ln S_i)^2 + a_4 \ln L_i + a_5(\ln L_i)^2 + a_6 D_i + a_7 D_i^2 \\
&+ a_8 D_i^3 + a_9 \ln S_i \times \ln L_i + a_{10} \ln S_i \times D_i + a_{11} \ln L_i \times D_i \\
&+ X_i b + N_j + Q_t + \epsilon_{it}
\end{aligned}$$

- A_i: Age of property (building) i
- $f(A_i, \ln S_i, \ln L_i, D_i)$: Nonparametric, linear, pairwise linear, step

Empirical Results

- **CRS** in Japan, **DRS** in the U.S. (Centre County)
- Land & structure are **substitutes** in Japan and the U.S.
- Land value share **higher** in Japan (60-70%) than U.S. (10%)
- Property depreciation rate **larger** for properties
  - newer, denser, far from CBD, in smaller city
- Structure depreciation rate **larger**
  - in Japan (6.4-7.0%) than in the U.S. (1.5%, residential)
  - for commercial (9.1%-10.2%) than for residential

Comment 1: Theoretical vs Empirical Specification of $V_{t,u}$

Theoretical Model

$$V_{t,u} = P_t^H(\alpha(E_u S)^{\frac{\theta-1}{\theta}} + (1-\alpha)L^{\frac{\theta-1}{\theta}})^{\frac{\eta\theta}{\theta-1}} \tag{1}$$

Empirical Specification

$$\begin{aligned}
\ln V_{ijt} &= a_0 + f(A_i, \ln S_i, \ln L_i, D_i) \\
&+ a_2 \ln S_i + a_3(\ln S_i)^2 + a_4 \ln L_i + a_5(\ln L_i)^2 + a_6 D_i + a_7 D_i^2 \\
&+ a_8 D_i^3 + a_9 \ln S_i \times \ln L_i + a_{10} \ln S_i \times D_i + a_{11} \ln L_i \times D_i \\
&+ X_i b + N_j + Q_t + \epsilon_{it} \qquad (2)
\end{aligned}$$

Propositions derived from (1) valid for (2)?

Theoretical Implications with General Production Function

$$\max_{S,L} P_t^H H_t(E_u S, L) - P_t^{ES} E_u S - P_t^L L$$

FOC

$$\frac{P_t^{ES} E_u S}{V_{t,u}} \quad (\equiv s_{tu}) = \frac{\partial \ln H_t(E_u S, L)}{\partial \ln S} = \frac{\partial \ln P_t^H H_t(E_u S, L)}{\partial \ln S}$$

$$\frac{P_t^L L}{V_{t,u}} \quad (\equiv l_{tu}) = \frac{\partial \ln H_t(E_u S, L)}{\partial \ln L} = \frac{\partial \ln P_t^H H_t(E_u S, L)}{\partial \ln L}$$

Thus,

$$s_{tu} + l_{tu} = \underbrace{\frac{\partial \ln H_t(E_u S, L)}{\partial \ln S} + \frac{\partial \ln H_t(E_u S, L)}{\partial \ln L}}_{\text{Elasticity of scale at } (E_u S, L)}$$

elasticity of scale

Theoretical Implications Cont'd

$\boldsymbol{s_{tu} + l_{tu}}$ **informative about (local) returns to scale.**

$-\frac{\partial \ln P_t^H H_t(E_u S, L)}{\partial u} = \delta_u s_{tu}$ **holds w/o parametric assumptions**

Elasticity of substitution $\boldsymbol{\sigma(S, L)}$

- Not sure if $\frac{\partial s_{tu}}{\partial u}$ useful (yet)...
- Compute $\sigma(S, L)$ using estimated $V_{tu} = P_t^H H_t(E_u S, L)$?

Comment 2: Obsolescence (Cohort Effects) in $V_{t,u}$?

Controlling for year of construction in hedonic regression?

- Obsolescence due to technological progress

  (e.g. revision of earthquake resistance standard in Japan)
- Collinearity between age, time, & cohort.
  - Age & time (Done) or Age & cohort
  - Age, cohort, & 'normalized' time effect (Aguiar & Hurst, 2013)

Comment 3: Ask Structure Depreciation in Appraisal?

Can ask depreciation schedule in real estate appraisal?

- e.g. The Real Estate Transaction Promotion Center

Compare with estimated depreciation rates?

Backup Slides

Digression: Elasticity of Scale

Let $f(\mathbf{x})$ be production function. Define y by $y(t) = f(t\mathbf{x})$. The **elasticity of scale** $e(\mathbf{x})$ is given by

$$e(\mathbf{x}) \equiv \frac{dy(t)}{dt}\frac{t}{y}\Big|_{t=1}$$

Technology exhibits **locally increasing, constant, or decreasing returns to scale** as

$$e(\mathbf{x}) \gtreqless 1$$

Fact.

$$e(\mathbf{x}) = \sum_{i=1}^{n} \frac{\partial \ln f(\mathbf{x})}{\partial \ln x_i}$$

Go back