Economic Measurement Group Workshop Sidney 2013

Separating the Age Effect from a Repeat Sales Index:

Land and Structure Decomposition

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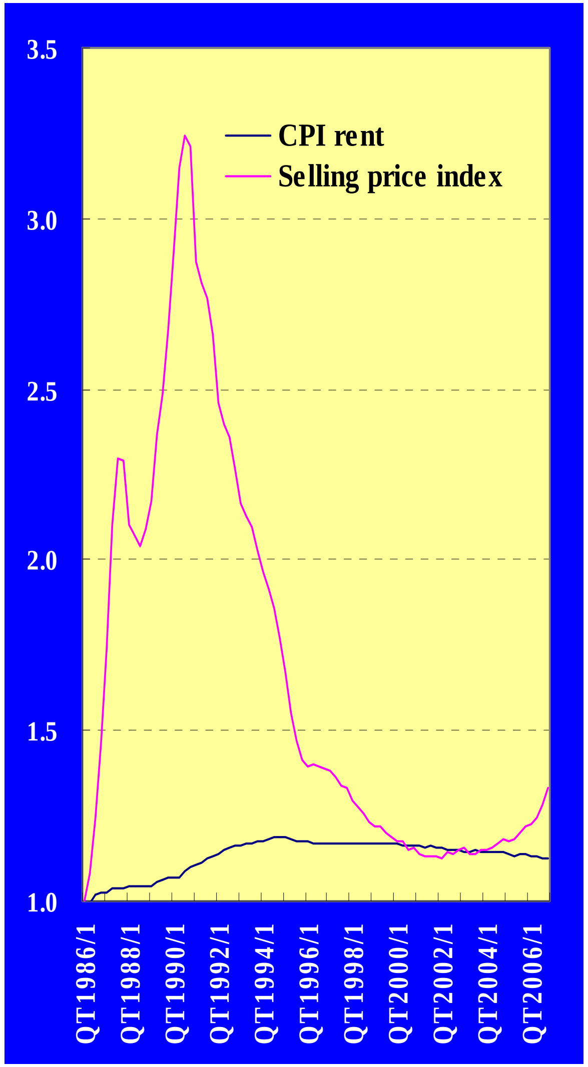
0. Background

- **1. Major part of Japanese CPI**

Expenditures for housing services:	**26.3%**
Housing rents:	**5.8%**
Imputed rents from owner occupied housing:	**18.6%**
Housing maintenance and others:	**1.9%**
"Consumer Price Index (CPI) in Tokyo, 2005"	

- **2.Stickey Rent for OOH**
- Shimizu,C, K.G.Nishimura and T.Watanabe(2009), "Residential Rents and Price Rigidity: Micro Structure and Macro Consequences," NBER-TRIO meeting 2009

- **3.Linckage to Asset prices**
- **Goodhart (2001)** :The housing rent is a key variable linking asset prices and the indices of goods and services prices, like the CPI.



1. Purpose and Motivation

- For price indexes for property, the core problem is that it is heterogeneous and infrequently traded.

- Mean or median price indices are simple to compute, but properties sold in one period may differ from those in another period.

- To overcome this problem, two regression-based approaches are used to construct a quality-adjusted property price index.

- **Hedonic Method and Repeat Sales Method**

Problems in Repeat Sales Measure

- The repeat sales model is challenged for making a fundamentally incorrect assumption:
- Quality does not change over time even for the ***same property***.

- For example, a repeat sales index may wrongly capture the price increase of a property due to ***the addition of a bedroom*** or ***renovation***.

- But this is not the failure of the repeat sales model. If the change is known, the repeat sales model can be easily modified to account for it (Bailey, Muth and Nourse, 1963, p.935).

Disadvantage in Repeat Sales in *RPPI handbook*

- a) The method is ***inefficient*** in the sense that it does not use all of the available transaction prices; it uses only information on units that have sold more than once during the sample period.
- **b)** The basic version of the method ignores (net) ***depreciation*** of the dwelling unit.
- c) There may be a ***sample selection bias*** problem in repeat sales data.
- **d)** The method ***cannot provide separate price indexes for land and for structures***.
- …………………………………..

Depreciation Problem in Repeat Sales Method:

- "*Unfortunately, a* ***depreciation adjustment cannot be readily estimated*** *along with the price index using our regression method… Assuming that properties depreciate at a constant rate per unit time, … the x matrix [regressors] is singular… In applying our model, therefore, additional information would be needed in order to adjust the price index for depreciation.*"

- (Bailey, Muth and Nourse, 1963, p.936).

Previous researches about Age-adjusted RS

- Palmquist (1980) proposed a **two-stage method**: first obtain an independent estimate of the deprecation rate from the hedonic price.
- Case and Quigley (1991), Hill,et al (1997), and Englund, et al (1998) offered a similar idea but combined the hedonic and repeat sales regressions into a **hybrid model** for joint estimation.
- Chau, Wong, and Yiu (2005) , Shimizu, Nishimura and Watanabe(2010), Karato, Movshuk and Shimizu (2010) found another instrument to **separate the age and time effects. (cohort effect)**
- Cannaday, Munneke, and Yang (2005) , had to drop two age dummies arbitrarily in order to avoid perfect collinearity, although a high degree of collinearity still remains.

Land and Structure Problem:

- "*At the national level, statistical agencies need to construct overall values of land and structures for the National Balance Sheets for the nation. If a user cost approach is applied to the valuation of Owner Occupied Housing services, it is necessary to have a decomposition of housing values into land and structures components* ***since structures depreciate while land does not.*** "

- Diewert, de Haan and Hendriks (2011a)(2011b),
- Diewert and Shimizu (2013).

2. An age-adjusted repeat sales model

- Value (P) is the sum of land value (L) and structure value (S). The value of a new property is:

- (1) $P(0) = L + S(0)$

- After A periods, the property reaches age A.
- (2) $P(A) = L + S(0) \times (1 - \delta \boldsymbol{A})$

- (3) $P(A) = L + S(0) \times \left[1 - \delta \boldsymbol{g}(\boldsymbol{A})\right]$

Depreciation for Property

***Ratio of new structure value to new property value**

- (4) $$\frac{P(A)-P(0)}{P(0)} = -\frac{S(0)}{P(0)}\delta g(A)$$

  $\frac{S(0)}{P(0)} \rightarrow R(0)$

(a) The same δ (e.g. building technology) for all structures, properties in a high land value area would depreciate more slowly than those in a low land value area.

(b) If the structure depreciates at a constant rate, the property's depreciation rate is likely to be time-varying because structure and land values do not move at the same pace.

Price Structure

- **Hedonic price equation**:
- Age term: (4) $\frac{P(A)-P(0)}{P(0)} = -\frac{\boldsymbol{S(0)}}{\boldsymbol{P(0)}}\delta g(A)$
- (5) $lnP_{it} = X_i\beta + \alpha_t - \delta \boldsymbol{R_t} g(A_{it}) + \varepsilon_{it}$
- A non-linear depreciation pattern of the structure, the age function, ***g(A$_{it}$)***, adopts the Box-Cox transformation as shown in Equation6
- (6) $g(A_{it}) = \frac{A_{it}^{\lambda}-1}{\lambda}$

An age-adjusted repeat sales model

- Property *i* is sold twice at time ***s*** and ***t*** (where *t*>*s*) and there is no change in property attributes between the sales.
- Age-adjusted repeat sales model can be derived from the (*t*-*s*)th difference of Equation 5:

- (7) $\ln\left(\frac{P_{it}}{P_{is}}\right) = (\alpha_t - \alpha_s) - \delta[R_t g(A_{it}) - R_s g(A_{is})]$
- $+ (\varepsilon_{it} - \varepsilon_{is})$

- (5-*t*) $lnP_{it} = X_i\beta + \alpha_t - \delta \boldsymbol{R_t} g(A_{it}) + \varepsilon_{it}$
- (5-*s*) $lnP_{is} = X_i\beta + \alpha_s - \delta \boldsymbol{R_s} g(A_{is}) + \varepsilon_{is}$

3.Estimated results of the age-adjusted repeat sales model

- **3.1. Data**
- **Area:** Hong Kong and Tokyo.
- **Period:** The time period runs from **1993Q1 to 2012Q2**.
- **Number of observations:** **190,890** pairs of repeat sales in Hong Kong Island were collected from the EPRC database,
- **36,212** pairs in the special 23 wards of Tokyo from a weekly magazine Shukan Jutaku Joho (Residential Information Weekly) published by Recruit Co., Ltd.,
- **Prices:** The average sale price in Hong Kong is HK$4-5 million (US$600,000), whereas the average price in Tokyo is ¥30-40 million (US$400,000).

Table 1: Descriptive statistics of the repeat sales data in Hong Kong and Tokyo

Hong Kong Island

	Price at 1st sale (HK$ million)	Price at 2nd sale (HK$ million)	Age at 1st sale (quarters)	Age at 2nd sale (quarters)
Mean	4.0267	4.7299	**63.32**	**81.72**
Std.Dev.	5.3257	6.9459	43.11	43.41
Minimum	0.101	0.101	1	2
Maximum	184.8	338	230	246

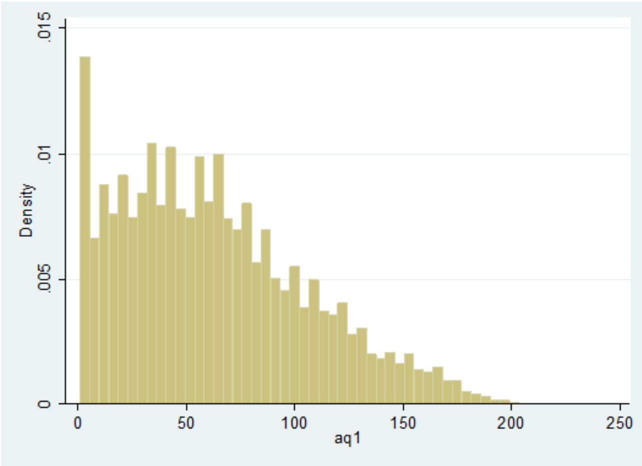
N=190,890

Tokyo

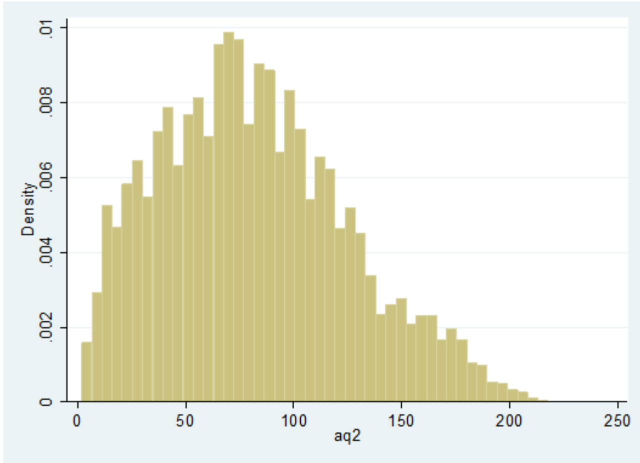
	Price at 1st sale ¥10,000	Price at 2nd sale ¥10,000	Age at 1st sale (quarters)	Age at 2nd sale (quarters)
Mean	3,998.36	3,402.43	**61.45**	**76.78**
Std.Dev.	3,180.38	2,582.23	34.73	36.86
Minimum	34	9	1	2
Maximum	80,000.00	68,000.00	192	201

N=36,212

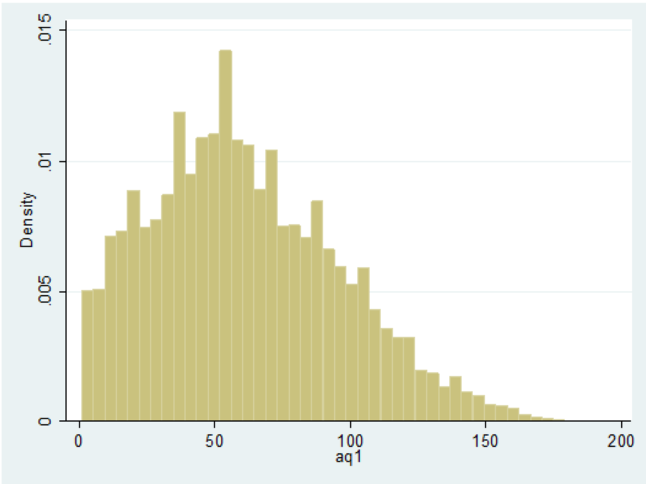
Histogram of Age of Building in Hong Kong and Tokyo



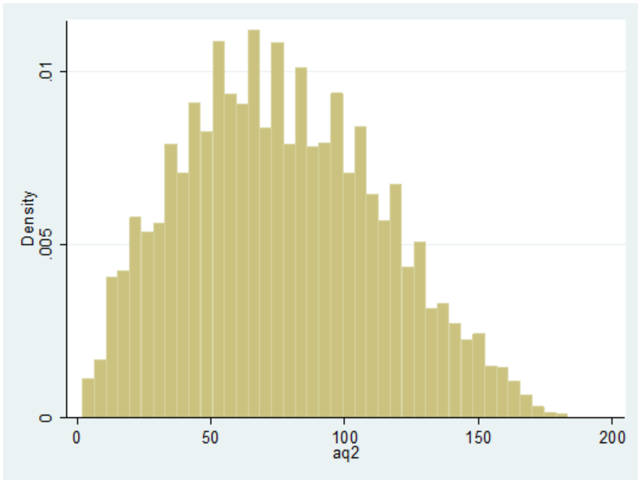
Histogram of Age（Hong Kong, 1st Transaction, quarter）



Histogram of Age（Hong Kong, 2nd Transaction, quarter）

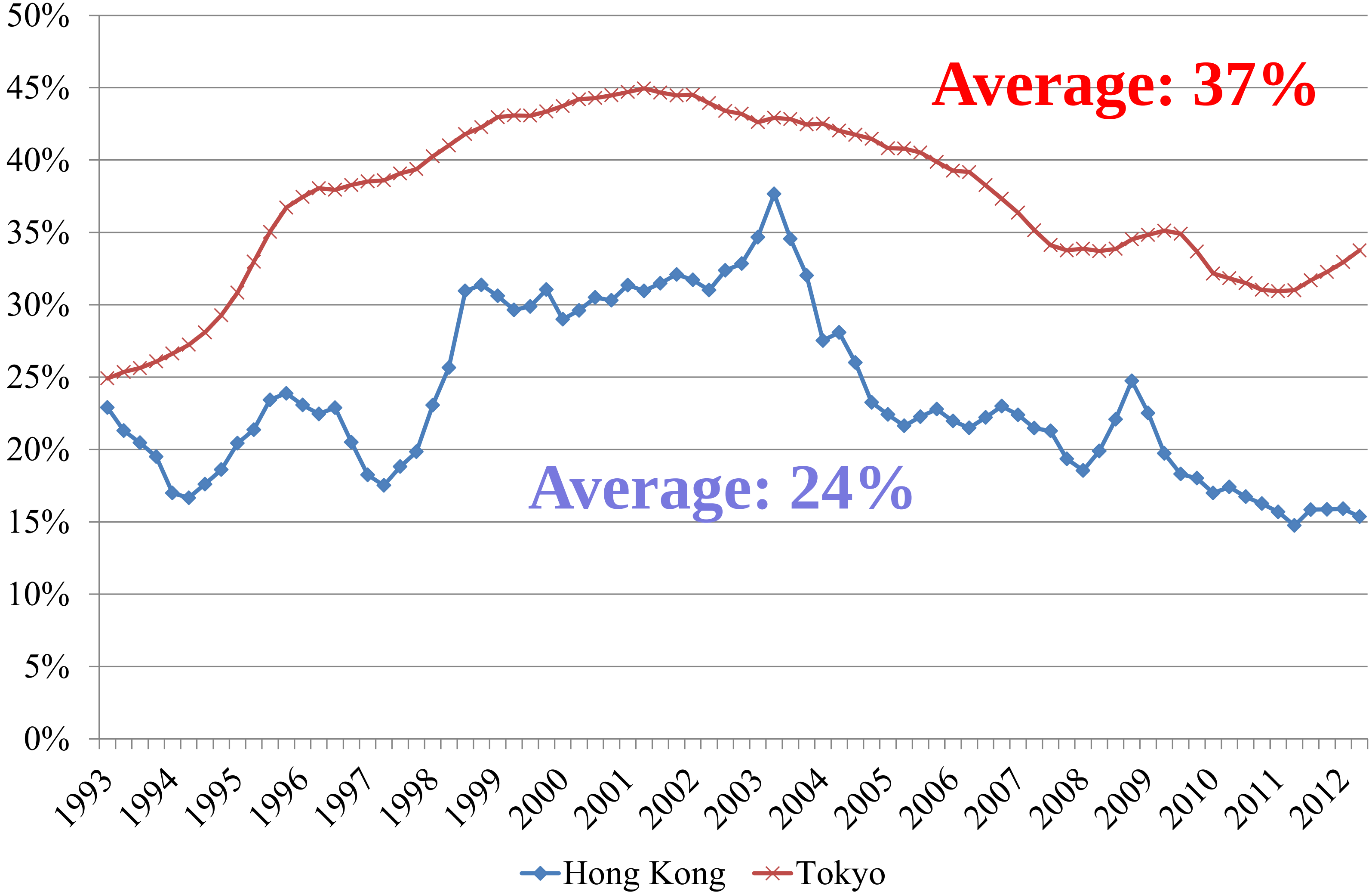


Histogram of Age（Tokyo, 1st Transaction, quarter）



Histogram of Age（Tokyo, 2nd Transaction, quarter）

Figure 1: Ratio of construction cost to average property price



3.2. Results

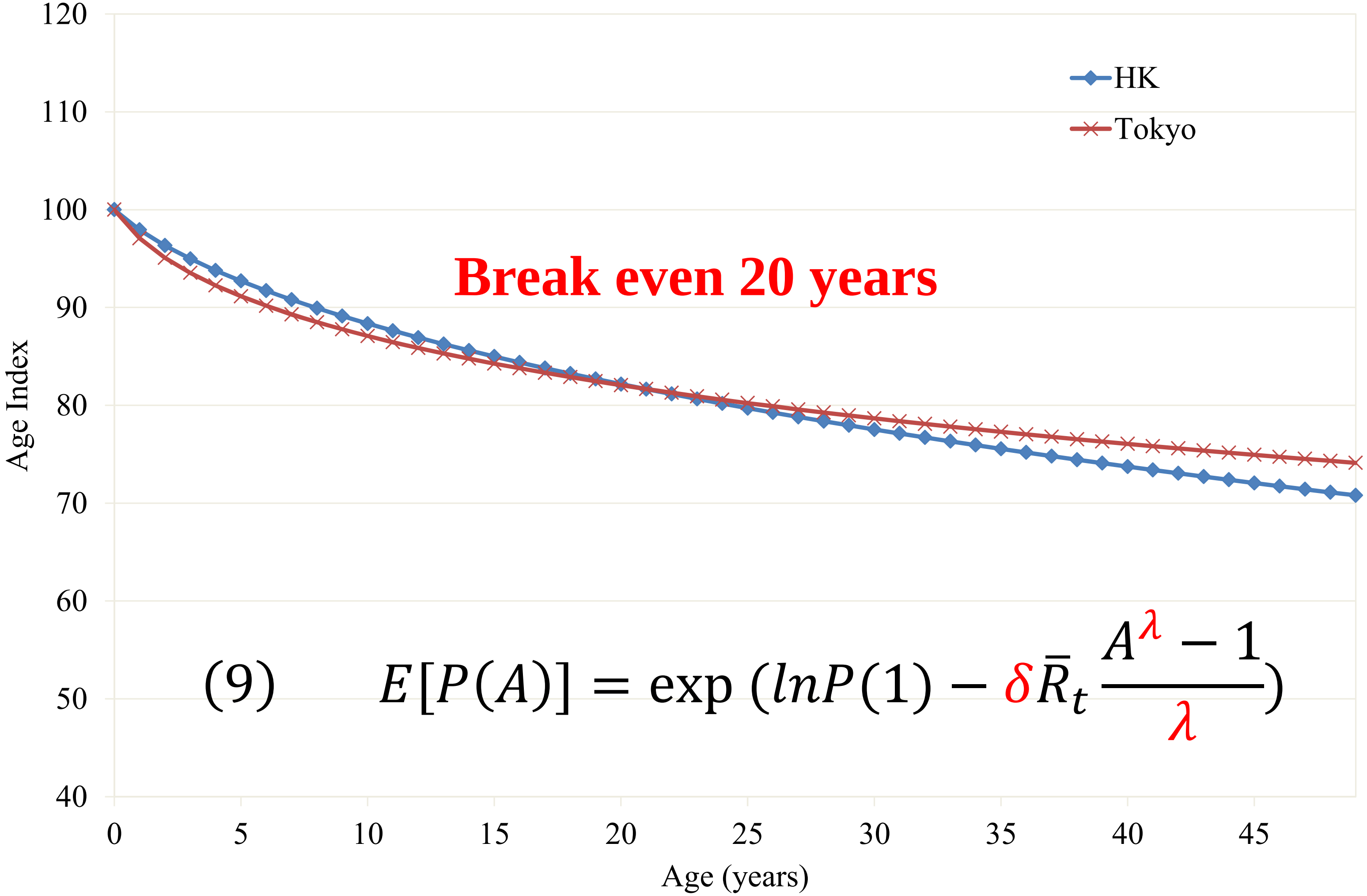
- The maximum likelihood estimates of the parameters δ and λ in Equation 7.
- (7) $\ln\left(\frac{P_{it}}{P_{is}}\right) = (\alpha_t - \alpha_s) - \delta[R_t g(A_{it}) - R_s g(A_{is})] + (\varepsilon_{it} - \varepsilon_{is})$
- With Box-Cox transformation, the marginal effect of age on log price is:
- (8) $E[lnP(A)] = -\delta R_t A^{\lambda-1}$ for $A > 0$

Table 2: Maximum likelihood estimates of the age effect

	Hong Kong Island	Tokyo
δ	**0.1029***	**0.1035***
λ	0.5547*	0.3212*
Log-likelihood	-19,185.82	11,097.23

Note: * significant at the 1% level

Figure 2: Property depreciation pattern in Hong Kong (HK) and Tokyo



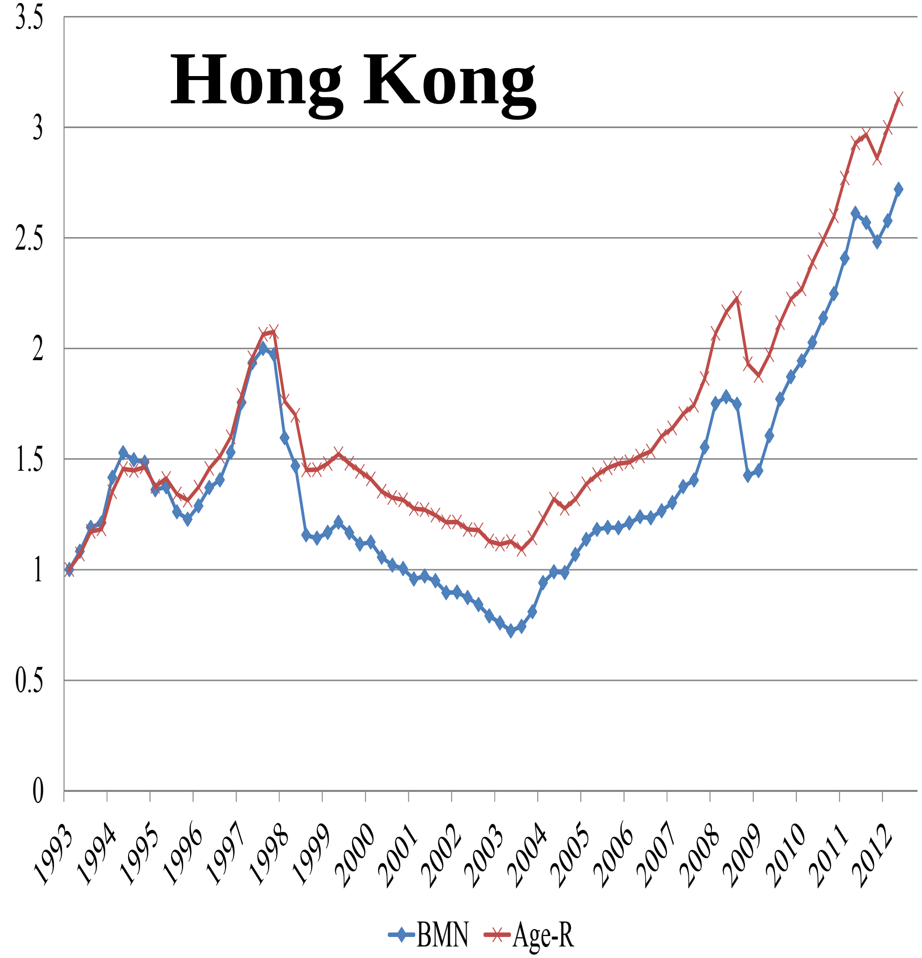
$$(9) \qquad E[P(A)] = \exp\left(lnP(1) - \delta \bar{R}_t \frac{A^{\lambda} - 1}{\lambda}\right)$$

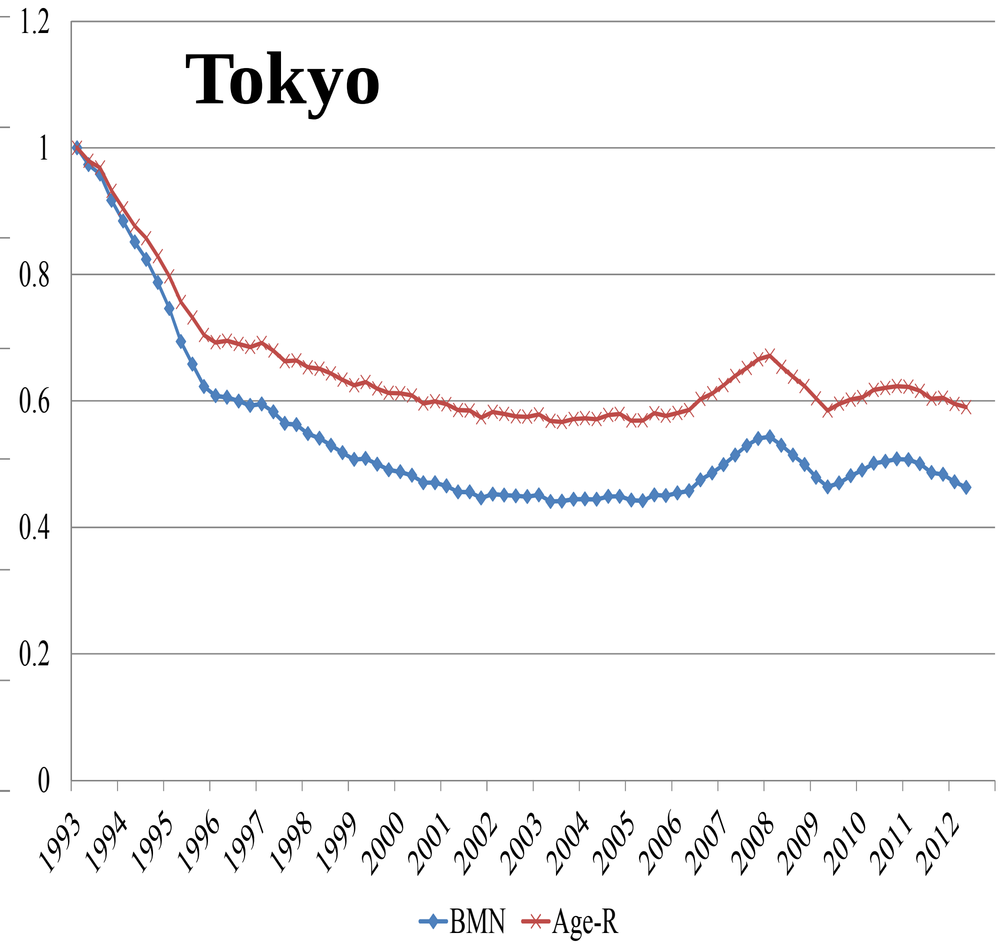
Table 6: Average annual depreciation rate

	Age adjusted RS (HK)	Age adjusted RS (TKO)	Hedonic (TKO)	Hybrid (TKO)
over 50 yrs	**-0.58%**	**-0.52%**	-1.14%	-1.18%
over 40 yrs	-0.65%	-0.59%	-1.29%	-1.27%
0-10 yrs	-1.09%	-1.22%	-2.36%	-1.51%
10-20 yrs	-0.64%	-0.53%	-1.47%	-1.51%
20-30 yrs	-0.51%	-0.38%	-1.23%	-1.51%
30-40 yrs	-0.44%	-0.30%	-1.09%	-1.51%
40-50 yrs	-0.40%	-0.26%	-1.00%	-1.51%

*Average annual depreciation rate from accumulate depreciation

Figure 3&4: Repeat sales indices in Hong Kong & Tokyo





$$(7)\quad \ln\left(\frac{P_{it}}{P_{is}}\right) = (\boldsymbol{\alpha_t - \alpha_s}) - \delta[R_t g(A_{it}) - R_s g(A_{is})] + (\varepsilon_{it} - \varepsilon_{is})$$

Table 3: Descriptive statistics of the BMN and Age-R indices

	Hong Kong Island	Tokyo
Age-R		
Mean return per quarter	**1.63%**	**-0.67%**
Return volatility per quarter	5.26%	1.71%
BMN		
Mean return per quarter	**1.56%**	**-0.97%**
Return volatility per quarter	7.05%	2.18%
Age adjustment in property return (per quarter)	**0.07%**	**0.30%**

The age adjustment is larger for Tokyo than Hong Kong because Tokyo has a larger component of structure relative to land.

4. Comparison with other traditional models

- **4.1. Hybrid Model and Hedonic Model**
- (10)

$$y_{it} \equiv \ln P_{it} = X_i' \beta + \delta A_{it} + \alpha_t + \varepsilon_{it}$$

Hill, Knight, and Sirmans (1997) distinguished the time effect and age effect by refining Case and Quigley's (1991).

- (11)

$$Y_i = y_{it} - y_{is} = \ln \frac{P_{it}}{P_{is}} = \tau_i \delta + \alpha_t - \alpha_s + v_i$$

$$(i = 1, 2, \cdots, N_R)$$

- (12)

$$\begin{pmatrix} y \\ Y \end{pmatrix} = \begin{pmatrix} X & A & d \\ 0 & \tau & D \end{pmatrix} \begin{pmatrix} \beta \\ \delta \\ \alpha \end{pmatrix} + \begin{pmatrix} \varepsilon \\ \upsilon \end{pmatrix}$$

- (13)

$$\ln P_{it} = X_i' \beta + \delta \frac{A_{it}^{\lambda} - 1}{\lambda} + \alpha_t + \varepsilon_{it}$$

4.2. Estimated results of Hybrid and Hedonic Model

- In the Tokyo data, **there is sufficient attribute data (characteristics)** about condominiums to estimate a hedonic function.

- Thus, the hybrid method that was proposed to modify the repeat sales method proposed by Case and Quigley (1991) may also be applied.

- Here, to appraise the new Age-R proposed in the preceding section, we decided to compare the price indices estimated by the ***hedonic method*** and the ***hybrid method*** using **Tokyo Data**.

Table 4:Descriptive statistics of the repeat sales data and hedonic data in Tokyo

		Mean	Std. Dev.	Min	Max
Hedonic Sample	Price (¥10,000)	3,637.92	2,684.75	185	112,000
	Age (quarters)	68.45	41.93	0	352

N=375,374

		Mean	Std. Dev.	Min	Max
Repeat Sales Sample	Price at 1st sale (¥10,000)	3,998.36	3,180.38	34	80,000
	Price at 2nd sale (¥10,000)	3,402.43	2,582.23	9	68,000
	Age at 1st sale (quarters)	61.45	34.73	1	192
	Age at 2nd sale (quarters)	76.78	36.86	2	201

N=36,212

Repeat Sales measure is inefficient.

Table 5: Estimated results of Hedonic and Hybrid model in Tokyo

	Hybrid Model		Hedonic Model	
Variable	Coef.	*t*-value	Coef.	*t*-value
Age (δ)	-0.0046	-219.809	-0.0192	-72.135
Box Cox (λ)	—	—	0.6353	182.680
Log (Floor Space)	1.1021	568.018	1.0890	1330.660
Distance to Nearest Station	-0.0071	-42.0458	-0.0089	-121.360
Distance to Tokyo Sta.	-0.0257	-56.8187	-0.0058	-41.792
Building Construction Dummy			Yes	
Ward Dummy	Yes		Yes	
Time Dummies	Yes		Yes	
const.	4.860	416.450	5.041	659.798
Number of obs.	108,969		375,374	
R-squared	0.998		0.889	
Adjusted R-squared	0.998		0.889	
S.E. of regression	0.189		0.182	
Log likelihood	26915.9		106200.0	

4.3. Comparison for Age adjusted RS to traditional indexes

- The hybrid price index and hedonic price index almost overlap.

- The new repeat sales price index (Age-R) follows a similar trend but is less volatile.

- The BMN repeat sales price index is strongly biased downwards, and by analogy, there is a depreciation bias that was clear from this series of studies.

Figure 5: Comparison of BMN, age adjusted RS, Hedonic and Hybrid property price indexes in Tokyo

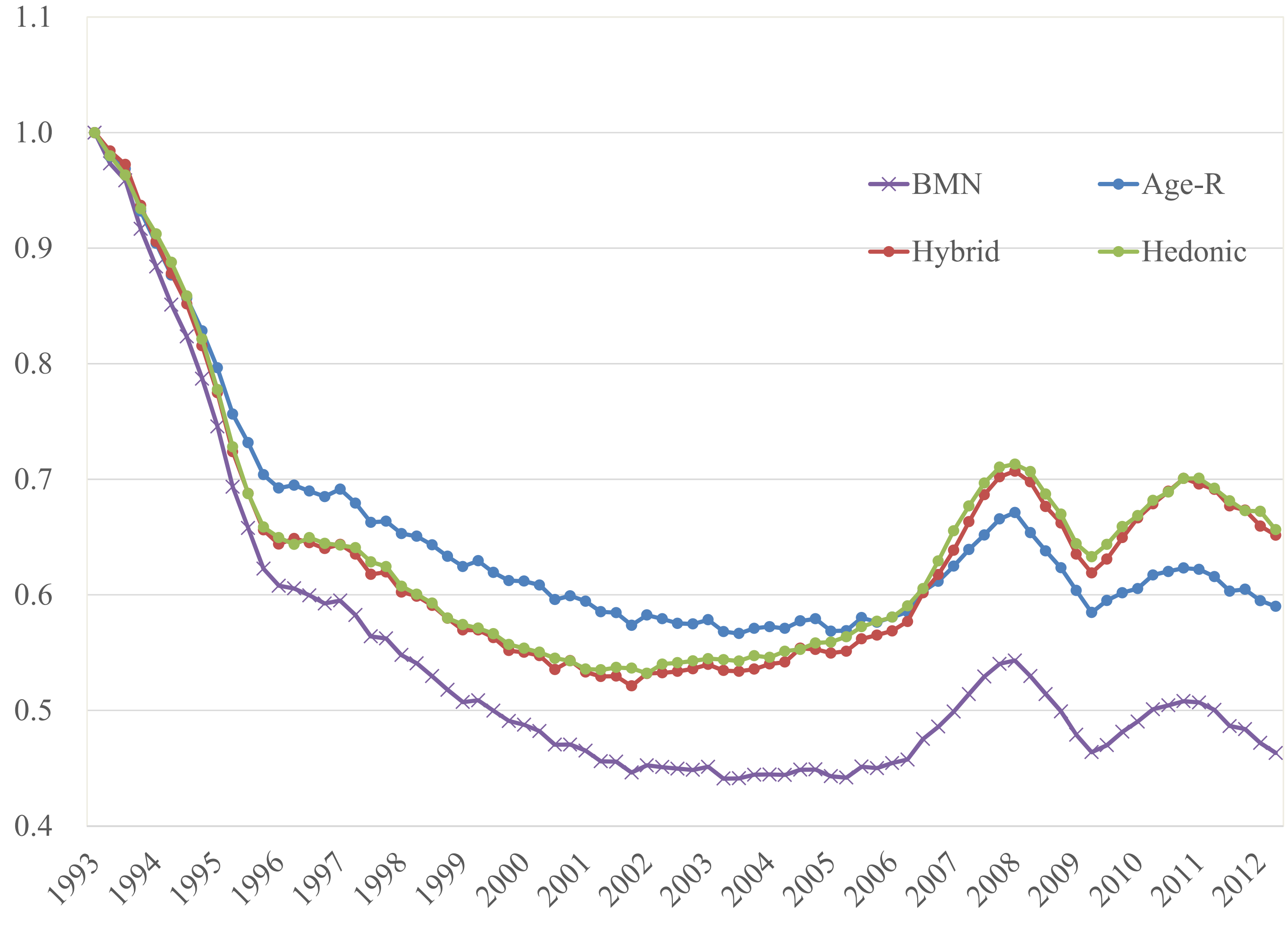


Figure 6: Comparison of Structure RS, Hedonic and Hybrid age indexes

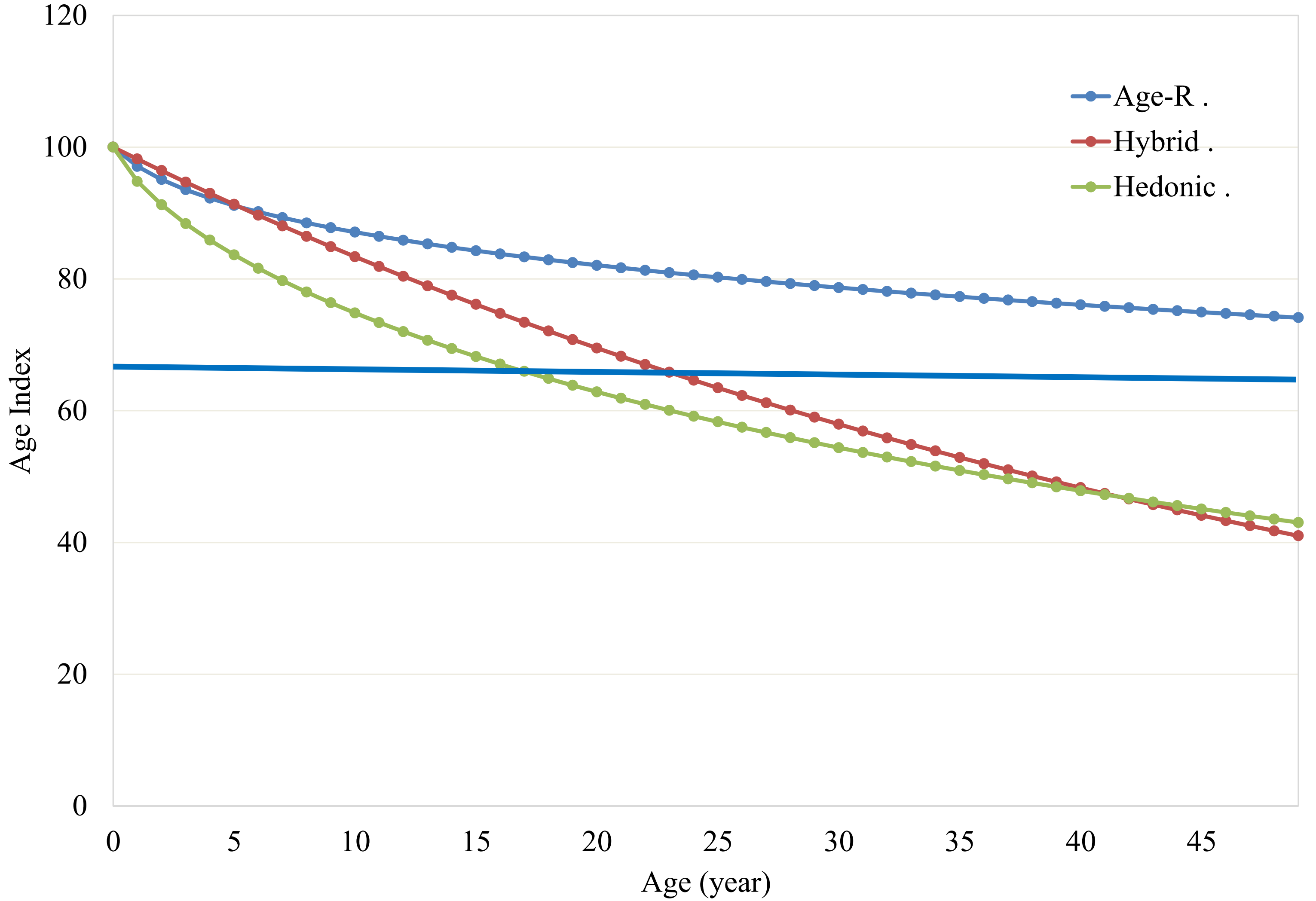


Figure 7: Marginal effect of depreciation rate

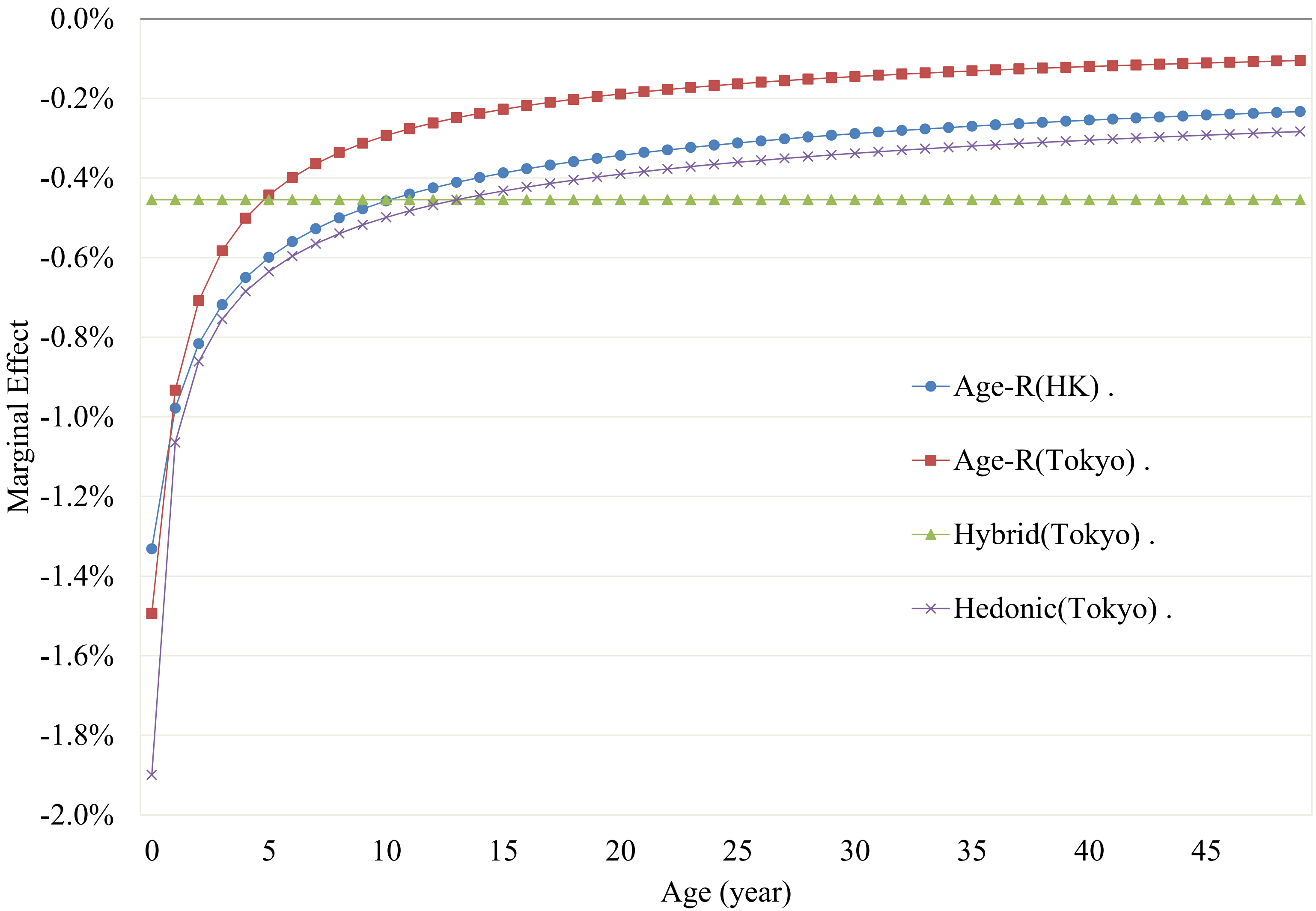


Table 6: Average annual depreciation rate

	Age adjusted RS (HK)	Age adjusted RS (TKO)	Hedonic (TKO)	Hybrid (TKO)
over 50 yrs	**-0.58%**	**-0.52%**	**-1.14%**	**-1.18%**
over 40 yrs	-0.65%	-0.59%	-1.29%	-1.27%
0-10 yrs	-1.09%	-1.22%	-2.36%	-1.51%
10-20 yrs	-0.64%	-0.53%	-1.47%	-1.51%
20-30 yrs	-0.51%	-0.38%	-1.23%	-1.51%
30-40 yrs	-0.44%	-0.30%	-1.09%	-1.51%
40-50 yrs	-0.40%	-0.26%	-1.00%	-1.51%

Table 3: Descriptive statistics of the BMN and Age-R indices

	Tokyo
Age-R	
Mean return per quarter	**-0.67%**
Return volatility per quarter	1.71%
BMN	
Mean return per quarter	**-0.97%**
Return volatility per quarter	2.18%
Age adjustment in property return (per quarter)	**0.30%**
Hybrid	
Mean return per quarter	**-0.53%**
Return volatility per quarter	2.21%
Hedonic	
Mean return per quarter	**-0.52%**
Return volatility per quarter	2.06%
Diffremces in property return with Hybrid (per quarter)	**-0.14%**
Diffremces in property return with Hedonic (per quarter)	**-0.15%**

5. Conclusions

- One of the major estimated model, RS fails to adjust for depreciation, as age and time between sales have an exact linear relationship. This paper proposes a new method to estimate an age-adjusted repeat sales index by decomposing property value into land and structure components.
- Based on housing transactions data from Hong Kong and Tokyo, Hong Kong has a higher depreciation rate (assuming a fixed structure-to-property value ratio), while the resulting age adjustment is larger in Tokyo because its structure component has grown larger from the first to second sales.
- The new Age-R is a valid means for solving the problem of depreciation bias.

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