

# Commercial Property Price Indexes and the System of National Accounts

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# 1. Introduction: Contents

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## 2. The Tokyo REIT Data

- This paper uses published information on the **Japanese Real Estate Investment Trust (REIT)** market in the Tokyo area.  
→ **IPD or Investment Property Data Bank in UK**
- **Balanced panel of observations on 50 REITs for 22 quarters**, starting in Q1 of 2007 and ending in Q2 of 2012.
- **V** : the assessed value of the property(yen)
- **CE**: the quarterly capital expenditures made on the property(yen)
- **L**: the area of the land plot in square meters (m<sup>2</sup>)
- **S**: the total floor area of the structure in m<sup>2</sup>
- **A**: the age of the structure in quarters

**Table 1: Descriptive Statistics for the Variables**

<b>Name</b>	<b>No. of Obs.</b>	<b>Mean</b>	<b>Std. Dev</b>	<b>Minimum</b>	<b>Maximum</b>
<b>V</b>	<b>1,100</b>	<b>4984.8</b>	<b>3417.8</b>	<b>984.3</b>	<b>18600</b>
<b>S</b>	<b>1,100</b>	<b>5924.8</b>	<b>3568.1</b>	<b>2099</b>	<b>18552</b>
<b>L</b>	<b>1,100</b>	<b>1106.3</b>	<b>718.2</b>	<b>294.5</b>	<b>3355</b>
<b>A</b>	<b>1,100</b>	<b>83.9</b>	<b>25.2</b>	<b>16.7</b>	<b>156.7</b>
<b>CE</b>	<b>1,100</b>	<b>6.08</b>	<b>11.94</b>	<b>0.06</b>	<b>85.49</b>

Balanced panel of observations on **50 REITs (Properties)** for **22 quarters**, starting in Q1 of 2007 and ending in Q2 of 2012.

### 3. The Asset Value Price Index for Commercial Properties in Tokyo: Basic model

- Denote the estimated asset value for REIT  $n$  during quarter  $t$  by  $V_{tn}$  for  $t = 1, \dots, 22$  and  $n = 1, \dots, 50$  where  $t=1$  corresponds to the first quarter of 2007 and  $t = 22$  corresponds to the second quarter of 2012.
- *If we ignore capital expenditures and depreciation of the structures on the properties, each property can be regarded as having a constant quality over the sample period.*
- Thus each property value at time  $t$  for REIT  $n$ ,  $V_{tn}$ , can be decomposed into a **price component,  $P_{tn}$** , times a **quantity component,  $Q_{tn}$** , which can be regarded as being constant over time.

## Lowe (1823) index:

- We can choose units of measurement so that each quantity is set equal to unity.
- Thus the price and quantity data for the 50 REITs has the following structure:  $Q_{tn} \equiv 1$ ;  $P_{tn} = V_{tn}$  for  $t = 1, \dots, 22$  and  $n = 1, \dots, 50$ .
- The *asset value price index* for period  $t$  for this group of REITs is the following **Lowe (1823) index**:
  - (1)  $P_A^t \equiv \sum_{n=1}^{50} P_{tn} Q_{1n} / \sum_{n=1}^{50} P_{1n} Q_{1n} = \sum_{n=1}^{50} V_{tn} / \sum_{n=1}^{50} V_{1n}$  ;
  - $t = 1, \dots, 22$ .
- **This index is very much analogous to a *repeat sales index*, except instead of using actual transaction prices, we use the assessed values or appraisal value for the properties.**

## Three major problems with the assessed value price index:

- a) The index relies on assessed values for the properties and **there is some evidence that assessed values are smoother and lag behind indexes** that are based strictly on sales at market values;(Shimizu and Nishimura (2006) )
- b) The index **does not take into account that *capital expenditures*** will generally change the quality of each property over time (so that the  $Q_{tn}$  are not in fact constant) and
- c) The index **does not take into account *depreciation*** of the underlying structure, which of course also changes the quality of each property.

## 4. A National Balance Sheet Accounting Approach to the Construction of Commercial Property Price Indexes.

- National income accountants build up capital stock estimates for a production sector *by deflating investments* by asset and then *adding up depreciated* real investments made in prior periods.
- For commercial *property capital expenditures* and the expenditures on the initial structure, we will more or less follow national income capital stock construction procedures.
- We will assume that the assessed values for each property represents a good estimate for the **total value of the structure and the land that the structure sits on.**



## Sum of three components= $V_{tn}$

- We postulate that the assessed asset value of REIT n in quarter t,  $V_{tn}$ , is equal to the sum of three components:
- The *value of the land plot*  $V_{Ltn}$  for the property;
- The *value of the structure* on the property,  $V_{Stn}$ , and
- The *value of the cumulated (but also depreciated) capital expenditures* on the property made in prior periods,  $V_{CEtn}$ .

	a)	b)	c)
•	(2)	$V_{tn} = V_{Ltn} + V_{Stn} + V_{CEtn}$ ;	
		$n = 1, \dots, 50$ ; $t = 1, \dots, 22$ .	

## a) *The value of the land plot* $V_{Ltn}$

- We start off by considering the decomposition of the **property land values,  $V_{Ltn}$ , into price and quantity components**; i.e., we assume that the following equations hold:

$$\bullet \quad (3) \quad V_{Ltn} = P_{Ltn} Q_{Ltn} ; Q_{Ltn} = L_{tn} = L_n ; \\ n = 1, \dots, 50 ; t = 1, \dots, 22$$

- where  $L_n$  (which is equal to  $L_{tn}$ ) is the area of the land plot for REIT  $n$ , which is part of our data base (and constant from period to period), and  $P_{Ltn}$  is the price of a square meter of land for REIT  $n$  in quarter  $t$  (which is not known yet).

## b) The *value of the structure on the property*, $V_{Stn}$

- (4)  $V_{Stn} = .3P_{St}S_{tn}(1-\delta_S)^{A(t,n)}$  ;  
 $n = 1, \dots, 50$  ;  $t = 1, \dots, 22$
- where  $A(t,n) \equiv A_{tn}$ . Thus we obtain the following decomposition of  $V_{Stn}$  into price and quantity components:
- (5)  $V_{Stn} = P_{Stn}Q_{Stn}$  ;  $P_{Stn} \equiv P_{St}$  ;  $Q_{Stn} \equiv .3S_{tn}(1-\delta_S)^{A(t,n)}$  ;  
 $n = 1, \dots, 50$  ;  $t = 1, \dots, 22$
- where  $P_{St}$  is the known official construction price index for quarter  $t$  (lagged one quarter),  $S_{tn}$  is the known floor space for REIT  $n$  in quarter  $t$ ,  $A(t,n)$  is the known age of REIT  $n$  in quarter  $t$  and  $\delta_S = 0.005$  is the assumed known quarterly geometric structure depreciation rate.

## c) *The value of the cumulated (but also depreciated) capital expenditures on the property*

- Define the capital expenditures of REIT  $n$  in quarter  $t$  as  $CE_{tn}$ .
- We need a deflator to convert these nominal expenditures into real expenditures. It is difficult to know precisely what the appropriate deflator should be.
- We will simply assume that the official structure price index,  $P_{St}$ , is a suitable deflator. Thus define *real capital expenditures* for REIT  $n$  in quarter  $t$ ,  $q_{CEtn}$ , as follows:

- **(6)**  $q_{CEtn} \equiv CE_{tn}/P_{St} ; n = 1, \dots, 50 ; t = 1, \dots, 22.$

## Definition of 3 components for Commercial Property

- The above material shows how to construct estimates for the price of land, structures and capital expenditures for each REIT  $n$  for each quarter  $t$  ( $P_{Ltn}$ ,  $P_{Stn}$  and  $P_{CEtn}$ ) and the corresponding quantities ( $Q_{Ltn}$ ,  $Q_{Stn}$  and  $Q_{CEtn}$ ).
- Now use this price and quantity information in order to construct *quarterly value aggregates* (over all 50 REITs in our sample) for the properties and for the land, structure and capital expenditure components; i.e., make the following definitions:

$$(12) \quad V^t \equiv \sum_{n=1}^{50} V_{tn} ; \quad V_L^t \equiv \sum_{n=1}^{50} V_{Ltn} ; \quad V_S^t \equiv \sum_{n=1}^{50} V_{Stn} ; \\ V_{CE}^t \equiv \sum_{n=1}^{50} V_{CEtn} ; \quad t = 1, \dots, 22.$$

## Laspeyres land price indexes

- Define the *Laspeyres chain link land index* going from quarter  $t-1$  to quarter  $t$ ,  $P_{L, Land}^{t-1,t}$ , as follows:

- (13)  $P_{L, Land}^{t-1,t} \equiv \sum_{n=1}^{50} P_{Ltn} Q_{L,t-1,n} / \sum_{n=1}^{50} P_{L,t-1,n} Q_{L,t-1,n}$  ;  
 $t = 2, 3, \dots, 22$ .

- The above chain links are used in order to define the *overall Laspeyres land price indexes*,  $P_{L, Land}^t$ , as follows:

- (14)  $P_{L, Land}^1 \equiv 1$  ;  $P_{L, Land}^t \equiv P_{L, Land}^{t-1} P_{L, Land}^{t-1,t}$  ;  
 $t = 2, 3, \dots, 22$ .

- Thus the Laspeyres price index starts out at 1 in period 1 and then we form the index for the next period by updating the index for the previous period by the chain link indexes defined by (13).

## Paasche chain link land index

- Define the *Paasche chain link land index* going from quarter  $t-1$  to quarter  $t$ ,  $P_{P, \text{Land}}^{t-1, t}$ , as follows:

$$(15) P_{P, \text{Land}}^{t-1, t} \equiv \frac{\sum_{n=1}^{50} P_{Ltn} Q_{Ltn}}{\sum_{n=1}^{50} P_{L, t-1, n} Q_{Ltn}} ;$$

$$t = 2, 3, \dots, 22$$

- The above chain links are used in order to define the overall Paasche land price indexes,  $P_{P, \text{Land}}^t$ , as follows:

$$(16) P_{P, \text{Land}}^1 \equiv 1 ; P_{P, \text{Land}}^t \equiv P_{P, \text{Land}}^{t-1} P_{P, \text{Land}}^{t-1, t} ;$$

$$t = 2, 3, \dots, 22.$$

## Fisher ideal land price index

- The sequences of Laspeyres and Paasche land price indexes,  $P_{L, \text{Land}}^t$  and  $P_{P, \text{Land}}^t$ , have been constructed, the ***Fisher ideal land price index*** for quarter  $t$ ,  $P_{F, \text{Land}}^t$ , is defined as the geometric mean of the corresponding Laspeyres and Paasche indexes; i.e., define
- **(17)  $P_{F, \text{Land}}^t \equiv [P_{L, \text{Land}}^t P_{P, \text{Land}}^t]^{1/2}$  ;  
 $t = 1, \dots, 22.$**
- **The Fisher chained price indexes for structures and capital expenditures**,  $P_{F, S}^t$  and  $P_{F, CE}^t$ , are constructed in an entirely analogous way, except that the REIT micro price and quantity data on land,  $P_{Ltn}$  and  $Q_{Ltn}$ , are replaced by the corresponding REIT micro price and quantity data on structures,  $P_{Stn}$  and  $Q_{Stn}$ , or on capital expenditures,  $P_{CEtn}$  and  $Q_{CEtn}$ , in equations (13)-(17).



## Overall chained Fisher property price index

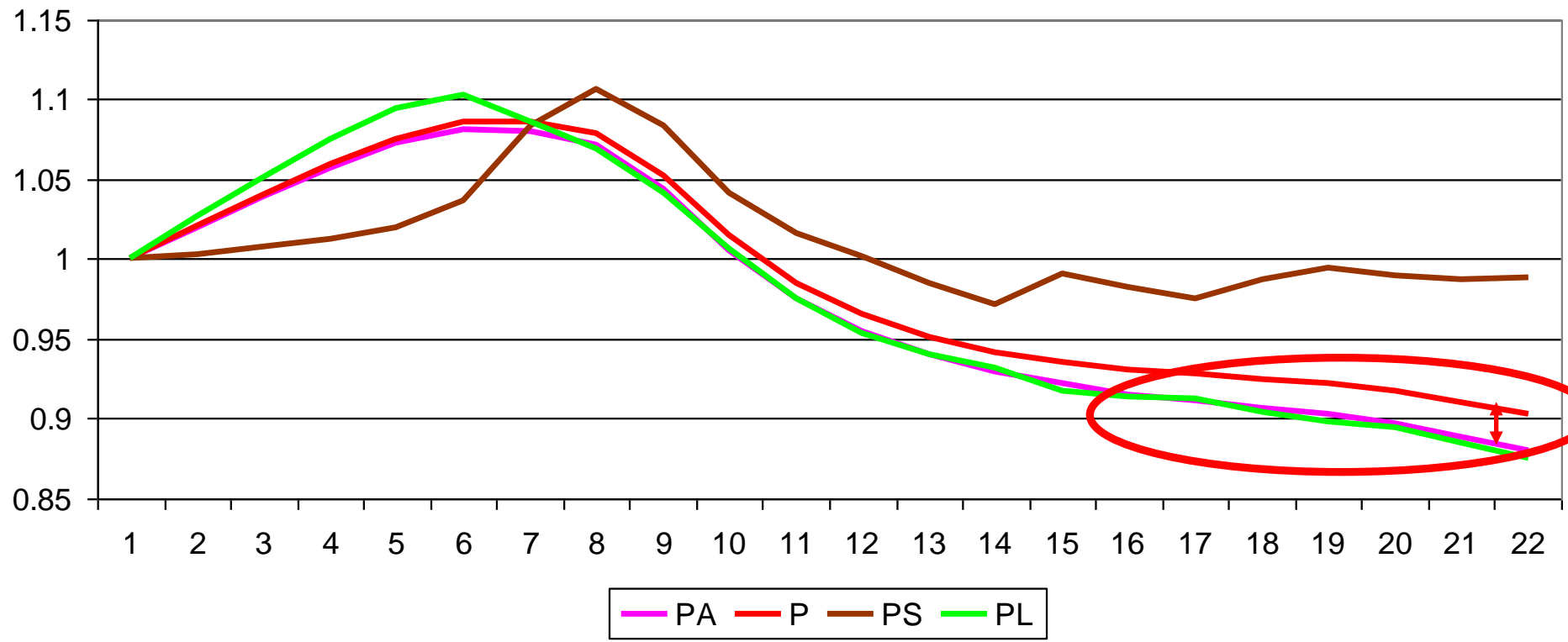
- The price series  $P^t$ ,  $P_L^t$ ,  $P_S^t$  and  $P_{CE}^t$  can be used to deflate the corresponding aggregate value series defined above by (12),  $V^t, V_L^t, V_S^t$  and  $V_{CE}^t$ , in order to **form implicit quantity or volume indexes**; i.e., define the following aggregate quantity indexes:
- **(18)  $Q^t \equiv V^t/P^t$  ;  $Q_L^t \equiv V_L^t/P_L^t$  ;  $Q_S^t \equiv V_S^t/P_S^t$  ;  $Q_{CE}^t \equiv V_{CE}^t/P_{CE}^t$  ;  $t = 1, \dots, 22$ .**
- $Q^t$  can be interpreted as an estimate of the real stock of assets across all 50 REITs at the beginning of quarter  $t$ ,  $Q_L^t$  is an estimate of the aggregate real land stock used by the REITs and  $Q_{CE}^t$  is an estimate of the real stock of capital improvements made by the REITs since they were constructed. This remains constant over time since the quantity of land used by each REIT remained constant over time.

## Fisher implicit quantity indexes

- The Fisher price index of capital expenditures,  $P_{CE}^t$ , defined above also turns out to equal the official index,  $P_{St}$ .
- Thus the fairly complicated construction of the **Fisher implicit quantity indexes** that was explained above can be replaced by the following very simple shortcut equations:

$$(19) \quad Q_S^t = V_S^t / P_{St}; \quad Q_{CE}^t = V_{CE}^t / P_{St}; \\ t = 1, \dots, 22.$$

**Chart 1: Asset Value Price Index PA and Accounting Price Index P, Price of Structures PS and Price Index for Land PL**



## 5. Traditional Hedonic Regression Approaches to Index Construction

- Most hedonic commercial property regression models are based on the *time dummy approach* where the log of the selling price of the property is regressed on either a linear function of the characteristics or on the logs of the characteristics of the property along with time dummy variables.
- The time dummy method does not generate **decompositions of the asset value into land and structure components** and so it is not suitable when such decompositions are required but the time dummy method can be used to **generate overall property price indexes**, which can then be compared with the overall price indexes  $P_A^t$  and  $P^t$ .

## Time dummy hedonic regression model

- Recall that  $V_{tn}$  is the assessed value for REIT  $n$  in quarter  $t$ ,  $L_{tn} = L_n$  is the area of the plot,  $S_{tn} = S_n$  is the floor space area of the structure and  $A_{tn}$  is the age of the structure for REIT  $n$  in period  $t$ . In the time dummy linear regression defined below by (20), we have replaced  $V_{tn}$ ,  $L_{tn}$  and  $S_{tn}$  by their logarithms,  $\ln V_{tn}$ ,  $\ln L_{tn}$  and  $\ln S_{tn}$ . Our first time dummy hedonic regression model is defined for  $t = 1, \dots, 22$  and  $n = 1, \dots, 50$  by the following equations:

- (20)  $\ln V_{tn} = \alpha + \alpha_t + \beta \ln L_{tn} + \gamma \ln S_{tn} + \delta A_{tn} + \varepsilon_{tn}$**
- where  $\alpha_1, \dots, \alpha_{22}$ ,  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$  are 25 unknown parameters to be estimated and the  $\varepsilon_{tn}$  are independently distributed normal error terms with mean 0 and constant variance.

# The *overall commercial property price indexes* for Model 1

- We choose the following normalization:
- **(21)  $\alpha_1 = 0$ .**
- This normalization makes the overall commercial price index equal to 1 in the first period.
- The *overall commercial property price indexes* for Model 1,  $P_1^t$ , are defined as the exponentials of the estimated time coefficients  $\alpha_t$ :
- **(22)  $P_1^t \equiv \exp[\alpha_t]$  ;  
 $t = 1, \dots, 22$ .**
- The resulting overall commercial property price indexes generated by Hedonic Model 1, the  $P_1^t$ .

## Second time dummy hedonic regression model

- Second time dummy hedonic regression model is defined for  $t = 1, \dots, 22$  and  $n = 1, \dots, 50$  by the following equations:

- **(23)**  $\ln V_{tn} = \alpha + \alpha_t + \beta \ln L_{tn} + \gamma \ln S_{tn} + \delta A_{tn} + \omega_n + \varepsilon_{tn}$

- where  $\alpha_1, \dots, \alpha_{22}$ ,  $\omega_1, \dots, \omega_{50}$ ,  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$  are 76 unknown parameters to be estimated and the  $\varepsilon_{tn}$  are independently distributed normal error terms with mean 0 and constant variance.

## Extended hedonic model for depreciation

- We replace  $A_{tn}$  by the logarithm of  $A_{tn}$ , this leads to a regression model where all of the parameters are identified. Thus **our second linear regression model** is the following one which has 72 independent parameters:
  - (24)  $\ln V_{tn} = \alpha_t + \omega_n + \delta \ln A_{tn} + \varepsilon_{tn}$  ;  
 $t = 1, \dots, 22$  ;  $n = 1, \dots, 50$ .
- Equations (24) and (21) define Hedonic Model 2.
- The  $\alpha_t$  parameters explain how, on average, the property values of the REIT sample shift over time and the REIT specific parameters, the  $\omega_n$ , reflect the effect on REIT value of the size of the structure and the size of the land plot as well as any locational characteristics.

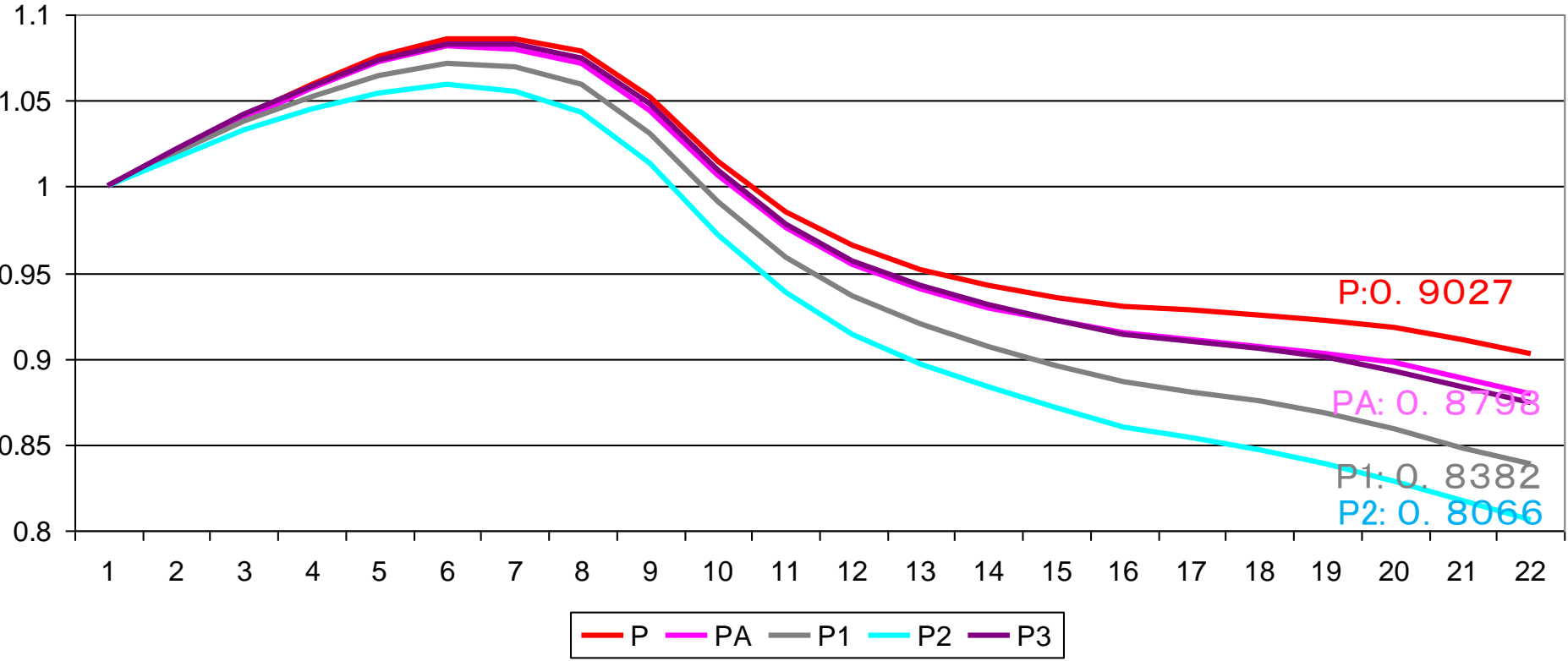


## The *overall commercial property price indexes* for Model 2

- The *overall commercial property price indexes* for Model 2,  $P_2^t$ , were defined as the exponentials of the estimated time coefficients  $\alpha_t$ :

- (25)  $P_2^t \equiv \exp[\alpha_t]$  ;  
 $t = 1, \dots, 22.$

### Chart 2: Accounting Price Index P, Asset Value Price Index PA and Hedonic Price Indexes P1, P2 and P3



## Two major problems with traditional log value hedonic regression

- There are two major problems with traditional log value hedonic regression models applied to property prices:
- These models often **do not generate reasonable estimates for structure depreciation** and
- These models essentially allow for only one factor that shifts the hedonic regression surface over time (the  $\alpha_t$ ) when in fact, there are generally two major shift factors: the price of structures and the price of land.
- **Unless these two price factors move in a proportional manner over time**, the usual hedonic approach will not generate accurate overall price indexes.

## 6. The Builder's Model Applied to Commercial Property Assessed Values

- The *builder's model* for valuing a commercial property postulates that the value of a commercial property is the sum of two components: **the value of the land which the structure sits on plus the value of the commercial structure.**
- The total cost of the property after the structure is completed will be equal to the floor space area of the structure, say  $S_{tn}$  square meters, times the building cost per square meter,  $\beta_t$  say, plus the cost of the land, which will be equal to the land cost per square meter,  $\gamma_{tn}$  say, times the area of the land site,  $L_{tn}$ .
- Thus if REIT  $n$  has a new structure on it at the start of quarter  $t$ , the value of the property,  $V_{tn}$ , should be equal to the sum of the structure and land value,  $\beta_t S_{tn} + \gamma_{tn} L_{tn}$ .

## Basic builder's model

- Assuming that we have information on the age of the structure  $n$  at time  $t$ , say  $A_{tn} \equiv A(t,n)$  and assuming a *geometric depreciation model*, a more realistic hedonic regression model is the following *basic builder's model*:

$$(26) \quad V_{tn} = \beta_t S_{tn} [e^\phi]^{A(t,n)} + \gamma_{tn} L_{tn} + \varepsilon_{tn} ; \\ t = 1, \dots, 22; n = 1, \dots, 50$$

- where the parameter  $e^\phi$  is defined to be  $1 - \delta$  and  $\delta$  in turn is defined as the quarterly depreciation rate for the structure.

## The Country Product Dummy methodology

- **Problem 1:** We have only 22 times 50 observations (1100 observations in all) on  $V$  but there are 1100 land price parameters  $\gamma_{tn}$  to be estimated;
  - **Problem 2:** The above model does not take into account the **capital expenditures** that were made in order to improve the structure after its initial construction.
  - → We deal with the first problem by applying **the Country Product Dummy methodology** to the land component on the right hand side of equations (26) above; i.e., we set
- (27)  $\gamma_{tn} = \alpha_t \omega_n$  ;  
 $t = 1, \dots, 22$ ;  $n = 1, \dots, 50$ .

## Nonlinear regression

- We also set the new structure prices for each quarter  $t$ ,  $\beta_t$ , equal to a single price of structure in quarter 1, say  $\beta$ , times our **official construction cost index**  $P_S^t$  described in earlier sections. Thus we have:
  - (28)**  $\beta_t = \beta P_S^t$  ;  
 $t = 1, \dots, 22$ .
- Replacing  $V_{tn}$  by  $V_{tn} - V_{CEtn}$  and substituting (27) and (28) into equations leads to the following nonlinear regression model:
  - (29)**  $V_{tn} - V_{CEtn} = \beta P_S^t S_{tn} [e^\phi]^{A(t,n)} + \alpha_t \omega_n L_{tn} + \varepsilon_{tn}$  ;  
 $t = 1, \dots, 22$ ;  $n = 1, \dots, 50$ .

## New land price series

- We need to explain how our new land price series  $P_{L4}^t$  can be combined with our structures (and capital expenditures) price series  $P_S^t$ . Denote the estimated Model 4 parameters as  $\beta^*$ ,  $\alpha_1^* \equiv 1$ ,  $\alpha_2^*, \dots, \alpha_{22}^*$ ,  $\phi^*$  and  $\omega_1^*, \dots, \omega_{50}^*$ .
- We can break up the fitted value on the right hand side of equation (29) for observation  $tn$  into *a fitted structures component*,  $V_{S4tn}^*$ , and *a fitted land component*,  $V_{L4tn}^*$ , for  $n = 1, \dots, 50$  and  $t = 1, \dots, 22$  as follows:

$$(30) \quad V_{S4tn}^* \equiv \beta^* P_S^t S_{tn} [e^{\phi^*}]^{A(t,n)} ;$$

$$(31) \quad V_{L4tn}^* \equiv \alpha_t^* \omega_n^* L_{tn}.$$



## Structure Value and Land Value

- Now form structures and capital expenditures aggregate (over all REITS),  $V_{S4t}^*$ , by adding up the fitted structure values  $V_{S4tn}^*$  defined by (30) and the capital expenditures capital stocks  $V_{CEtn}$  that were defined by equations (10) in section 4 for each quarter:

$$(32) \quad V_{S4t}^* \equiv \sum_{n=1}^{50} [V_{S4tn}^* + V_{CEtn}] ; \\ t = 1, \dots, 22.$$

- In a similar fashion, form a land value aggregate (over all REITS),  $V_{L4t}^*$ , by adding up the fitted land values  $V_{L4tn}^*$  defined by (31) for each quarter t:

$$(33) \quad V_{L4t}^* \equiv \sum_{n=1}^{50} V_{L4tn}^* ; \\ t = 1, \dots, 22.$$

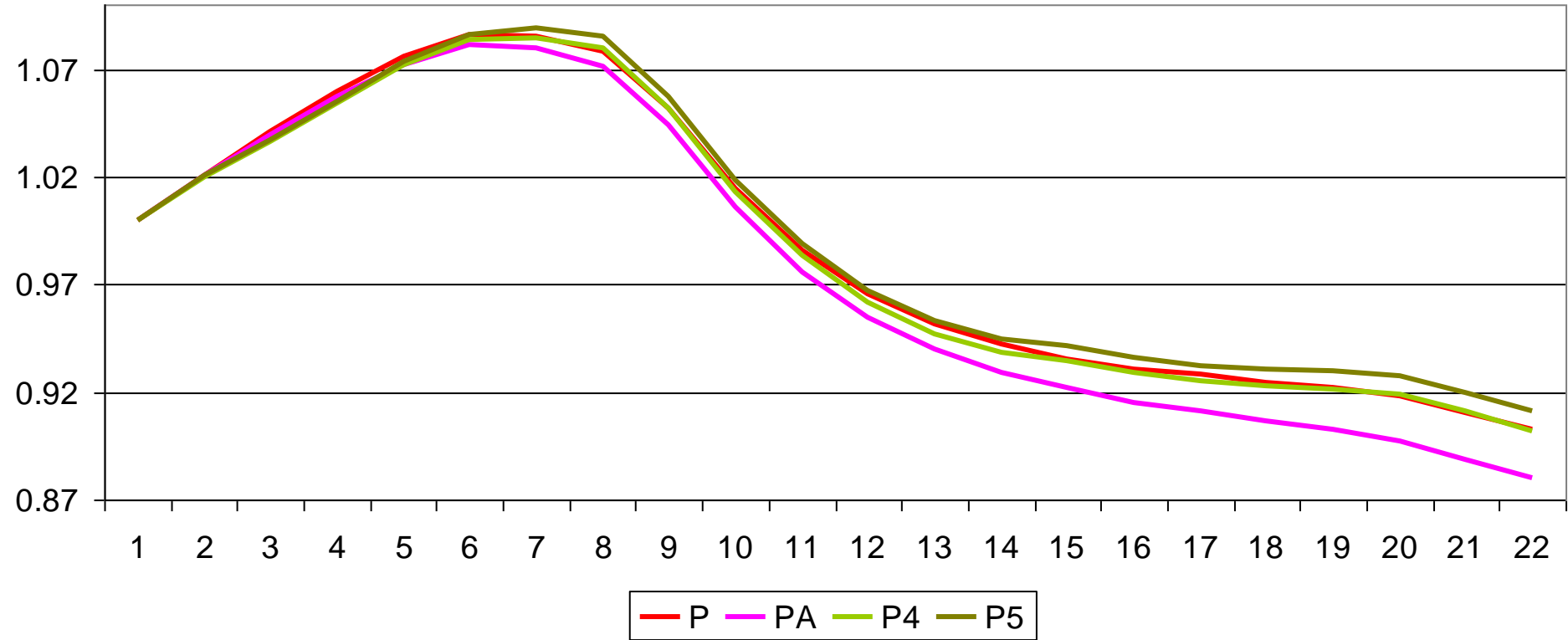
## The chained Fisher price index

- Now define the *period t aggregate structure* (including capital expenditures) *quantity* or volume,  $Q_{S4t}^*$ , by (34) and *the period t aggregate land quantity* or volume,  $Q_{L4t}^*$ , by (35):

- (34)  $Q_{S4t}^* \equiv V_{S4t}^*/P_S^t$  ;  
 $t = 1, \dots, 22$ ;
- (35)  $Q_{L4t}^* \equiv V_{L4t}^*/P_{L4}^t$  ;  
 $t = 1, \dots, 22$ .

- Thus for each period  $t$ , we have 2 prices,  $P_S^t$  and  $P_{L4}^t$ , and the corresponding 2 quantities,  $Q_{S4t}^*$  and  $Q_{L4t}^*$ . We form an overall commercial property price index,  $P_4^t$ , by calculating **the chained Fisher price index of these two price components**.

### Chart 3: Accounting Method Price Index P, Asset Value Index, Builder's Model Price Indexes P4 and P5



## Conclusion

- The traditional time dummy approach to hedonic property price regressions does not always work well. The basic problem is that there are two main drivers of property prices over time: changes in the price of land and changes in the price of structures. The hedonic time dummy method allows for only one shifter of the hedonic surface when in fact there are at least two major shifters. Moreover, the traditional approach does not lead to sensible decompositions of overall price change into land and structure component changes.
- The simple asset value price index suggested in section 3 seemed to work better than indexes based on the traditional time dummy hedonic regression approach.

- The accounting method for constructing land, structure and overall property price indexes that was described in section 4 turned out to generate price indexes that were pretty close to the hedonic indexes based on the builder's model that were developed in sections 6 and 7.
- The methods suggested in sections 4, 6 and 7 are **practical and probably could be used by statistical agencies to improve their balance sheet estimates for commercial properties.**
- We experimented with capitalizing REIT Net Operating Income into capital stock indexes but the volatility in REIT cash flows presents practical problems in implementing this method. Even after smoothing cash flows, we could not generate sensible capital stock estimates with our data set.

## Overall conclusion

- The constructing usable commercial property price indexes is a very challenging task;
- National statistical agencies have not had any experience to construct Commercial Property Statistics: a much more difficult task than the construction of residential property price indexes.
- The project of International Handbook on **COMMERCIAL PROPERTY PRICE INDICATORS** is a very challenging task; a much more difficult task than the construction of RPPI handbook.