Diewert and Shimizu: “Hedonic Regression Models for Tokyo Condominium Sales” – Discussion

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* This presentation represents the author’s personal opinions and does not necessarily reflect the views of the Deutsche Bundesbank or its staff.

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"A condominium is a form of multifurcated real property tenure. Specified units of the property are separately owned, and the remainder of the property is collectively owned. Unlike apartments, which are leased by their tenants, condominium units are owned outright." Source: Wikipedia, The Free Encyclopedia.

1. Introduction

- It is important to not only have estimates for the value of the housing stock but to **decompose the overall value into (additive) land and structure components** and then to further **decompose these value aggregates into constant quality price and quantity components**.

- The selling price values the sum of the structure and land components: **Property value = Structure value + Land value**.

- The problem of obtaining constant quality price components is further complicated by the fact that housing units are almost always unique assets: **Value change = Price change + Quality change**.

2. The Tokyo Condominium Data

- **Sales of condominium units**
  - located in nine wards in the **central area of Tokyo**
  - from the first quarter of 2000 to the first quarter of 2015 (**61 quarters**).

- In addition to the sales prices, **various characteristics of the properties**. (NB: "Sales price" here means listed price in the final week before a successful deal.)

- A total of **3,232 observations** (after range deletions to account for sparse tails of the variables and outliers in the data).

2. The Tokyo Condominium Data

Definitions of the variables and their units of measurement	
V	**Value** of the condo, in 10,000 yen
S	**Floor space** of the condo, in square metres
TS	**Total floor space** of the entire building, in square metres
TL	**Total lot area** for the entire structure, in square metres
A	**Age** of the structure, in years
H	**Number of the story** of the condo
TH	**Total number of stories** in the entire building
NB	**Number of bedrooms** in the condo
TW	**Walking time** to the nearest subway station, in minutes
TT	**Subway running time** to Tokyo station during the day, in minutes
SCR	**Reinforced concrete construction** dummy variable, 1 if reinforced
South	**South facing** dummy variable, 1 if condo faces south

3. The Basic Builder's Model

- Consider a property developer who builds a structure on a particular property: The **total cost of the property** after the structure is completed will be equal to
  - the **floor space area of the structure**, say S square meters, **times the building cost per square metre**, β_t during quarter t,
  - plus the cost of the **land**, which will be equal to the **cost per square metre**, α_t during quarter t, **times the area of the land site**, L.

- This leads to the following **hedonic regression model** for period t where the α_t and β_t are the parameters to be estimated in the regression:
  - (1) $V_{tn} = \alpha_t L_{tn} + \beta_t S_{tn} + \varepsilon_{tn}$, $t = 1, \ldots, 61$; $n = 1, \ldots, N_t$,
  - where the error terms ε_{tn} are assumed to be independently normally distributed with zero means and constant variances.

3. The Basic Builder's Model

- Assuming a **geometric depreciation model**, a more realistic hedonic regression model than that defined by (1) above is the following *basic builder's model*:
  - (2) $V_{tn} = \alpha_t L_{tn} + \beta_t (1 - \delta_t)^{A_{tn}} S_{tn} + \varepsilon_{tn}$,
  - where where the parameter δ_t reflects the *net geometric depreciation rate* as the structure ages one additional period, i.e. it is equal to a "true" gross structure depreciation rate less an average renovations appreciation rate.

- In order to deal with the **multicollinearity problem**, Diewert and Shimizu draw on *exogenous information* on the cost of building new condominium units from the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and they **assume that the price of new structures is proportional to an official index of condominium building costs**, p_{St}. Thus, they replace β_t in (2) by $\beta\, p_{St}$.

3. The Basic Builder's Model

- Each condo in the building should be allocated a *share* of the total land value of the property. There are two simple methods for constructing an appropriate **land share**:
  - (i) Use the **unit's share of floor space** to total structure floor space, or
  - (ii) simply use the **share of the total number of units** in the building.

- Thus, define the following two **land imputations** for unit n in period t:
  - (3a) $L_{Stn} = (S_{tn} / TS_{tn})\, TL_{tn}$;
  - (3b) $L_{Ntn} = (1 / N_{tn})\, TL_{tn}$,
  - where N_{tn} is the total number of units in the building for unit n sold in period t.

3. The Basic Builder's Model

- In order to allocate land across the N_{tn} units in a building, the unit shares should add up to one. However, the **shares** S_{tn} / TS_{tn}, if available for every unit in the building, **would add up to a number less than one** because the unit floor space areas, S_{tn}, if summed over all units in the building add up to **privately owned floor space** which is less than total building floor space TS_{tn}.

- An imperfect estimate of the ratio of privately owned floor space to total floor space for unit n in period t is N_{tn} S_{tn} / TS_{tn}. The sample wide average of these ratios was 0.899. Thus, to **account for shared structure space**, Diewert and Shimizu replaced the owned floor space variable in (2), S_{tn}, by (1 / 0.899) $S_{tn} \approx 1.1\ S_{tn}$.

- Diewert and Shimizu assumed that the **depreciation rate** δ_t was equal to 0.03:

  - (4) $V_{tn} = \alpha_{St} L_{Stn} + \beta_S p_{St} (1 - 0.03)^{A_{tn}} (1.1\ S_{tn}) + \varepsilon_{Stn}$,
  - (5) $V_{tn} = \alpha_{Nt} L_{Ntn} + \beta_N p_{St} (1 - 0.03)^{A_{tn}} (1.1\ S_{tn}) + \varepsilon_{Ntn}$.

3. The Basic Builder's Model

- The **estimates** for $\beta > 2$ were **totally unsatisfactory** because these parameters should have been close to unity.
- Moreover, the **land price indexes** that these regression models generated were **subject to excessive volatility**.

- In order to deal with the problem of too high estimates of β, Diewert and Shimizu decided to **set it equal to unity** rather than to estimate it.
- Moreover, they **temporarily put aside the problem of jointly determining land and structure value** to concentrate on determining sensible constant quality land prices.

3. The Basic Builder's Model

- Diewert and Shimizu assume that the **structure value** for unit *n* in period *t*, V_{Stn}, is defined as follows:
  - (6) $V_{Stn} = p_{St} (1 - 0.03)^{A_{tn}} (1.1\ S_{tn})$.

- Once the imputed value of the structure has been defined by (6), they define the **imputed land value** for condo *n* in period *t*, V_{Ltn} , by subtracting the imputed structure value from the total value of the condo unit:
  - (7) $V_{Ltn} = V_{tn} - V_{Stn}$.

- They use V_{Ltn} as the dependent variable and **attempt to explain variations in these imputed land values** in terms of the property characteristics.

4. – 10. Explaining Variations in the Imputed Land Values

4. Introduction of **Ward** Dummy Variables
5. Introduction of **Building Height** as an Explanatory Variable
6. Introduction of the **Height of the Unit** as an Explanatory Variable
7. Introduction of a More General **Method of Land Imputation**
8. Introduction of the **Number of Units in the Building** as an Explanatory Variable
9. Introduction of **Excess Land** as an Explanatory Variable
10. Introduction of **Subway Travel Times and Facing South** as Explanatory Variables

11. Using the Selling Price as the Dependent Variable

V_{tn} =		
	α_t	
×	$(\Sigma_j\ \omega_j\ D_{W,tn,j})$	Ward dummy variables
×	$(\Sigma_h\ \chi_h\ D_{TH,tn,h})$	Building height dummy variables
×	$(\Sigma_m\ \mu_m\ D_{EL,tn,m})$	Excess land dummy variables
×	$(\phi_1\ D_{s,tn,1} + \phi_2\ D_{s,tn,2})$	Facing south dummy variables
×	$[1 + \gamma\,(H_{tn} - 3)]$	Height of the unit
×	$[1 + \kappa\,(N_{tn} - 11)]$	Total number of units in the building
×	$[1 + \eta\,(TW_{tn} - 1)]$	Walking time to nearest subway station
×	$[1 + \theta\,(TT_{tn} - 12)]$	Subway running time to Tokyo station
×	$L_{tn}(\lambda)$	More general method of land imputation
+	$\mathbf{p_{St}\ (1 - \delta)^{A_{tn}}\ (1.1\ S_{tn})}$	**Structure component of the value**
+	ε_{tn}	

12. Adjusting the Quality of the Structure

- Diewert and Shimizu introduce the **number of bedrooms** variable, NB_{tn}, and the **reinforced concrete construction** dummy variable, SCR_{tn}, as quality adjusters for the value of the structure:

  - (26) $V_{tn} = \alpha_t \times (\Sigma_j\ \omega_j\ D_{W,tn,j}) \times (\Sigma_h\ \chi_h\ D_{TH,tn,h}) \times (\Sigma_m\ \mu_m\ D_{EL,tn,m})$
  $\times (\phi_1\ D_{s,tn,1} + \phi_2\ D_{s,tn,2}) \times [1 + \gamma\,(H_{tn} - 3)] \times [1 + \kappa\,(N_{tn} - 11)]$
  $\times [1 + \eta\,(TW_{tn} - 1)] \times [1 + \theta\,(TT_{tn} - 12)] \times L_{tn}(\lambda)$
  $+ p_{St} \times (1 - \delta)^{A_{tn}} \times \mathbf{(1 + \sigma\,SCR_{tn}) \times (\Sigma_i\ \rho_i\ D_{B,tn,i})} \times (1.1\ S_{tn}) + \varepsilon_{tn}.$

- A complete listing of the **estimated 101 coefficients** and their standard errors can be found in **Table 3 of the paper**.

- It is likely that the **model developed in section 13** (separate land price parameters for poor, medium and rich wards) is **not reliable**.

14. Constructing Land, Structure and Overall Property Price Indexes

– **Predicted land and structure values** for observation *tn*, $V_{Ltn}{}^*$ and $V_{Stn}{}^*$, can be defined as follows:

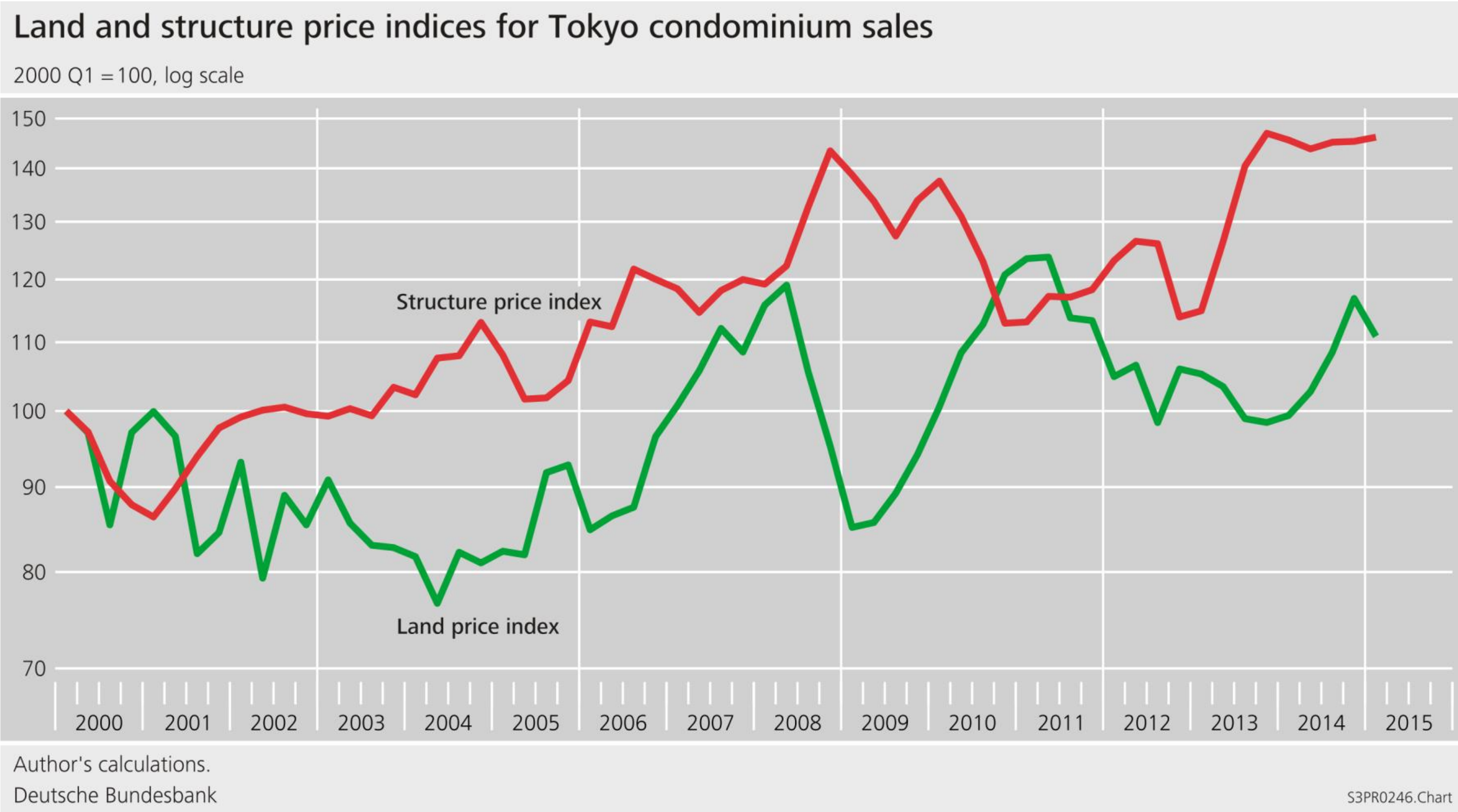
- (30) $V_{Ltn}{}^* = \alpha_t{}^* \times (\Sigma_j\ \omega_j{}^*\ D_{W,tn,j}) \times (\Sigma_h\ \chi_h{}^*\ D_{TH,tn,h}) \times (\Sigma_m\ \mu_m{}^*\ D_{EL,tn,m})$ $\times (\phi_1{}^*\ D_{s,tn,1} + \phi_2{}^*\ D_{s,tn,2}) \times [1 + \gamma^*\ (H_{tn} - 3)] \times [1 + \kappa^*\ (N_{tn} - 11)]$ $\times [1 + \eta^*\ (TW_{tn} - 1)] \times [1 + \theta^*(TT_{tn} - 12)] \times L_{tn}(\lambda^*);$

- (31) $V_{Stn}{}^* = p_{St} \times (1 - \delta^*)^{A_{tn}} \times (1 + \sigma^*\ SCR_{tn}) \times (\Sigma_i\ \rho_i{}^*\ D_{B,tn,i}) \times (1.1\ S_{tn}).$

– It can be seen that each term on the right hand side of (30) has $\alpha_t{}^*$ as a common factor. Thus, Diewert and Shmizu define $\alpha_t{}^*$ as the **price index for land** in period t, p_{Lt}.

– Each term on the right hand side of (31) has p_{St} as a common factor. Thus, it is natural to define this common factor p_{St} as the **price index for structures** in period t.

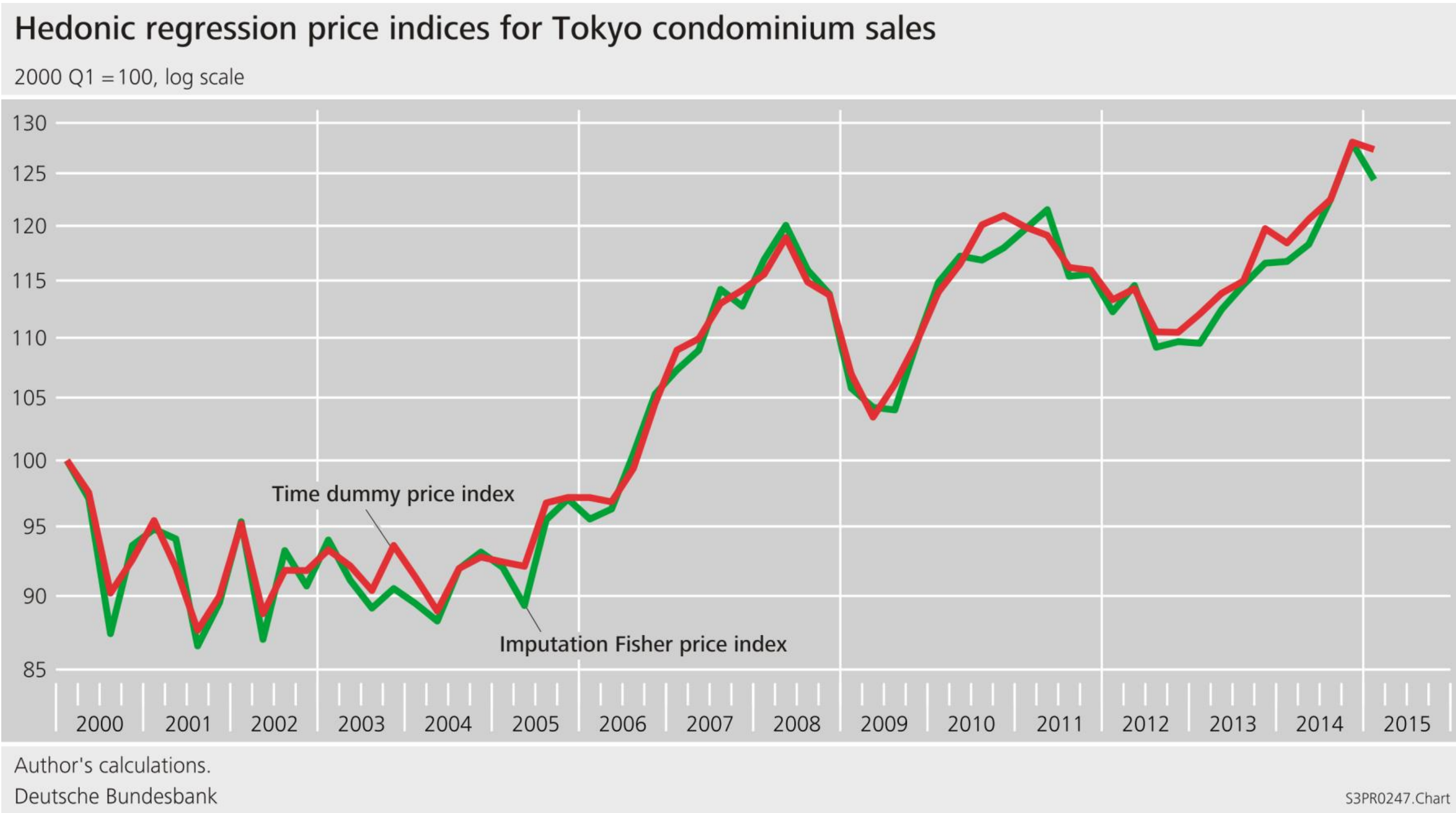
14. Constructing Land, Structure and Overall Property Price Indexes



15. Comparison with other Condo Price Indexes

- An **overall constant quality property price index** p_t is formed as a chained Fisher (hedonic imputation) index of the land and structure components.
- Diewert and Shimizu also plot a **traditional time dummy hedonic price index**, p_{TDt}.
- In order to construct this index they run a **linear regression**:
  - $\ln V_{tn} = c + (\Sigma_\tau \pi_\tau D_{T,tn,\tau}) + (\Sigma_j \omega_j D_{W,tn,j}) + \beta \ln S_{tn} + \alpha \ln L_{tn}$
    $+ \delta A_{tn} + \gamma H_{tn} + \rho NB_{tn} + \eta TW_{tn} + \theta TT_{tn}$
    $+ \sigma SCR_{tn} + \phi \text{South}_{tn} + \varepsilon_{tn}$
    $= 4.4850 + \boldsymbol{(\Sigma_\tau \pi_\tau^* D_{T,tn,\tau})} + (\Sigma_j \omega_j^* D_{W,tn,j}) + \mathbf{0.9158 \ln S_{tn} + 0.0203 \ln L_{tn}}$
    $\mathbf{- 0.0168\, A_{tn}} + 0.0076\, H_{tn} + 0.0034\, NB_{tn} - 0.0135\, TW_{tn} - 0.0094\, TT_{tn}$
    $- 0.0027\, SCR_{tn} + 0.0195\, \text{South}_{tn} + \varepsilon_{tn}^*;$
  - $p_{TDt} = \exp \pi_t^*$.

15. Comparison with other Condo Price Indexes



16. Conclusion

- The main focus of the paper has been to **suggest a method for decomposing condominium values into structure and land components**, where the structure value components are **consistent with existing national statistical agency practices** for the determination of apartment structure values.

- The **models need to be tested on other data sets and improvements to the basic methodology should be made**. However, the models presented in this paper provide a **starting point for further research**.

- Moreover, many of the explanatory characteristics that were used will probably be useful in **explaining commercial property prices**.

Discussion

− (1) $V_{tn} = \alpha_t L_{tn} + \beta_t S_{tn} + \varepsilon_{tn}$

- The **<u>costs</u> of developing a property** might not be a good proxy for its **<u>value</u>**, or as Oscar Wilde taught us in *The Picture of Dorian Gray*: “Nowadays people know the price of everything and the value of nothing.”

- This is because someone’s **willingness to pay** for the condominium may be determined by factors beyond the construction costs, or as *Aristotle* put it: “The whole is greater than the sum of its parts.”

− (2) $V_{tn} = \alpha_t L_{tn} + \beta_t (1 - \delta_t)^{A_{tn}} S_{tn} + \varepsilon_{tn}$

- How does **depreciation** fit into a **“<u>builder’s</u> model”**? If $A_{tn} = 0$ (newly built property), then (2) simplifies to (1).

Discussion

– (4) $V_{tn} = \alpha_{St} L_{Stn} + \beta_S p_{St} (1 - 0.03)^{Atn} (1.1\ S_{tn}) + \varepsilon_{Stn}$

- (i) β_t replaced by $\beta\, p_{St}$: Is the **assumption** that the price of new structures is proportional to an index of building costs **supported by the data**?
- (ii) S_{tn} replaced by 1.1 S_{tn}: What is the **variation between condos and over time** of this sample wide average adjustment for land imputation, is it robust?
- (iii) δ_t assumed to equal 0.03: On **which basis (data?)** is this number for the depreciation rate imputed? (Although it is estimated non time varyingly later.)

– (6) $V_{Stn} = p_{St} (1 - 0.03)^{Atn} (1.1\ S_{tn})$ (NB: No error term, since **no estimation**.)

- β set equal to 1: The **data contradict** this! Also, should p_{St} be a price index(?!), why should the parameter be unity?

Discussion

- (7) $V_{Ltn} = V_{tn} – V_{Stn}$
  - The structure value in (6) per square metre is, for a given age, proportional to an index of building costs and, hence, (7) is essentially the **residual value method**.
- Sections 4 – 10: Concentrating on explaining variations in these imputed land values and attempting to determine sensible constant quality land prices **does not solve the problem of jointly determining land and structure value**.
  - The methodology and results are **highly educational**, though!
  - At the end of the paper, **not much remains of the basic builder‘s <u>model</u>**, the approach is **mainly empirical** (but rightly so!).

Discussion

- **Increases in structure prices were driven by increasing construction costs due** to earthquakes and other disasters. It can be seen that as construction prices spike upwards, land prices tend to spike downwards.
  - Is it **sensible for the value of the property stock to be affected by abnormal developments in construction costs**?
  - Also, is the **spike downwards in land prices a direct result of this effect**, and if yes, how can this be explained (e.g. did overall values remain stable)?
- All of the R^2s reported in this paper are equal to the **square of the correlation coefficient between the dependent variable in the regression and the corresponding predicted variable**.
  - This is equivalent to the R^2 of a linear regression of the dependent variable on a constant and the predicted variable; are the **results consistent in a Mincer/Zarnowitz sense**, i.e. is the intercept zero and the slope unity?

Discussion

- The **formulation is designed to be useful for national income accountants** who require a decomposition of property value into structure and land components.

  - True but **also from a financial stability perspective this is highly relevant**. An important indicator is the **change in values – price changes including quality changes – of financed objects over time**.

  - This is because, from the banks‘ perspective, the **residual value of a home is of interest only should the debtor default**, since then the bank would have to sell the home on the market (possibly in a forced sale).

  - The quality of the house, however, is not fixed but it is assumed to be **subject to a constant annual depreciation rate**.

  - Hence, **for macroprudential purposes we need something like the age-price profile** in the SNA.