Decoupling Land Values in Residential Property Prices

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Outline

Introduction

- A property is a bundled good composed of an appreciating asset, land, and a depreciating asset, structure.
- The importance of this distinction is increasingly recognised in the real estate literature (see Bostic et al. (2009), Malpezzi et al. (1987)) as well as in the price index construction literature (see European Comission et al. (2013), Chapter 13, Diewert et al. (2011), Diewert et al. (2015), Diewert and Shimizu (2013) and Färe et al. (2015)).

Introduction (cont.)

- Due to the mobility of materials and labor, construction costs are generally uniform within a housing market
- Asymmetric appreciation across properties within a market arise from asymmetric exposure to common shocks to land values.
- At any point in time the value of the structure is its replacement cost less any accumulated depreciation.
- Sufficiently large depreciation can result in the structure declining in value over time
  - Malpezzi et al. (1987), Knight and Sirmans (1996), Bostic et al. (2009), Diewert et al. (2011, 2015)

Contributions

- Propose a filter based decomposition to separate the value of the land from that of the structure
  - Related to the literature where dynamics are used to identify unobserved components (Harrison (1965).Maravall and Aigner (1977),West and Harrison (1999),Harvey (2011),Komumjer and Ng (2014))
  - Alternative approach: use exogenous information - *new dwelling construction price index* to aid at identifying the land component Diewert et al. (2015), Diewert and Shimizu (2013) and Färe et al. (2015)
- Compare the decomposition approach between the cases when the data available include
  - both property and vacant land sales transactions
  - only property sale transactions
- Compare price indices to those obtained using Diewert et al. (2015), Diewert and Shimizu (2013) and Färe et al. (2015)

Outline

Valuer's Model

The valuer's task is to provide the tax authorities and the rate payers with a valuation of their property or land. We write a simple model for the expected value of the property,

$$E_t(V_t) = E_t[(Land_t + Struct_t) | \sum_{j=0}^{\tau} w_{t-j} \, [\text{market sales: } Property, Land]_{t-j}] \tag{1}$$

where,
V_t is the value of the property
$Land_t$ is the land component of the value
$Struct_t$ is the structure component of the property value
w_t is a weight such that $w_{t-1} > w_{t-2} > w_{t-3} > \ldots$

Outline

Econometric Model

This follows previous studies (Bostic et al. (2009) and Diewert et al. (2011, 2015) where three orthogonal components are defined, land (*Land*), structure (*Struct*) and noise.

$$y_t \quad = \quad Land_t + Struct_t + \epsilon_t \qquad (2)$$

where,
y_t is a vector ($N_t \times 1$) with the sale price of each property (or vacant land) sold in period t.
$Land_t$ is a vector ($N_t \times 1$) where each row is the value of the land component for the i^{th} property sold in period t
$Struct_t$ is a vector ($N_t \times 1$) where each row is the value of the structure component for the i^{th} property sold in period t, and
$Struct_{it} = 0$ if the sale is for vacant land
$\epsilon_t \sim N(0, \sigma_\epsilon^2 I)$

Econometric Model

- Let X_t^L be an $N_t \times k_l$ matrix of hedonic characteristics intrinsic to the land component, e.g. size of the lot, location
- Let X_t^S be an $N_t \times k_s$ matrix of hedonic characteristics intrinsic to the structure component, e.g. age, size of the structure
- Then define,

$$Land_t = f(X_t^L, \alpha_t^L) \tag{3}$$

$$Struct_t = g(X_t^S, \alpha_t^S) \tag{4}$$

where,
α_t^c are vectors of time-varying parameters capturing the trends in $c = Land, Struct$

- The simplest form of $f()$ and $g()$ is to use a linear combination: $Land_t = X_t^L \alpha_t^L$; $Struct_t = X_t^S \alpha_t^S$ with a filter updating of the form

$$\alpha_t^L = \alpha_{t-1}^L + G_t^L \nu_t \quad (5)$$

$$\alpha_t^s = \alpha_{t-1}^s + G_t^S \nu_t \quad (6)$$

where,
X_t^L are characteristics of the land (i.e., size and location), X_t^S are characteristics of the structure (i.e., size, age)

α_t^c, $c = Land, Struct$ measure willingness to pay for hedonic characteristics

$\nu_t = y_t - X_t^L \tilde{\alpha}_{t-1}^L - X_t^S \tilde{\alpha}_{t-1}^S$ vector of price prediction errors - for properties sold in in period t

G_t^c, $c = Land, Struct$, are functions of:
X_t^L, X_t^S,
covariance of ν_t,
covariance of $\tilde{\alpha}_t = [\tilde{\alpha}_t^L, \tilde{\alpha}_t^L]$,
two smoothing constants, variance of overall noise, and discounted past data and covariances

Modified Filter

- It is a modified form of the Kalman filter based on the dynamic discounting literature (see Harrison (1965),West and Harrison (1999),Koop and Korobilis (2013)).
- Assumptions:
  - X_t^L and X_t^S are not trending
  - *Land* component bear adjustments due to supply and demand pressures
  - *Structure component* depreciate with age, driven by construction costs in the local market.
  - The two smoothing constants, known as discount factors in this literature, each associated with one of the components. Obeying,
    - $0 < \delta_L < \delta_S \leq 1$,
    - Intuition: a discount factor equals to 1 implies the α_t^c is time-invariant

Estimation

- Only three parameters to estimate by maximum likelihood $\psi = \left[\sigma_\epsilon^2, \delta_L, \delta_S\right]$
  - maximise log-likelihood to estimate σ_ϵ^2, using grid search for discount factors, δ_L and δ_s
- With $\tilde{\psi}$ compute G_t^c, α_t^c and ν_t using modified filter algorithm
- Matlab code - runs in seconds.
- Can show that $\widehat{Land}_t = f(X_t^L \,|X_t^S)$ and $\widehat{Struct}_t = f(X_t^S \,|X_t^L)$

Index for the land component

- The **Fisher Plutocratic index** is defined as:

$$F^P_{(t-s),t} = \sqrt{L^P_{(t-s),t}\, P^P_{(t-s),t}} \quad (7)$$

where $L^p_{t-s,t}$ and $P^p_{t-s,t}$ are respectively the Laspeyres and Paasche index numbers,

$$L^p_{(t-s),t} = \sum_{h=1}^{N_s} w^h_{(t-s)} \left(\frac{\hat{P}^L_t(x^L_{(t-s)})}{\hat{P}^L_{(t-s)}(x^L_{(t-s)})} \right); \quad P^p_{(t-s),t} = \left[\sum_{h=1}^{N_t} w^h_t \left(\frac{\hat{P}^L_{(t-s)}(x^L_t)}{\hat{P}^L_t(x^L_t)} \right) \right]^{-1}$$

where,
$\hat{P}^L_{(t-s)}(x^L_t)$ for $s \geq 0$ is an *imputation* of the land component of h, sold at time t with characteristics x^L_t, using a vector of shadow prices for time period $t-s$ and the value shares defined as in (8).
w^h_t is given by:

$$w^h_t = \frac{P^h_t}{\sum_{n=1}^{N_t} P^n_t} \quad (8)$$

where,
P^h_t is the observed sale price of property/land h and N_t is the number of sales in period t.

- The **Fisher Democratic index** is that where $w^h_t = {}^1/N_t$

Outline

Empirical Evidence

1. Bay Area - Monthly Data, 1991-2010 (urban sprawling)
   - Homogeneous urban area north of Brisbane, $\approx$ 40 KM from CBD
   - Large proportion of commuters to Brisbane
   - Close to ocean and other waterways
2. Brisbane Suburb - Annual Data, 1970 - 2010
   - $\approx$5 KM from CBD
   - Old, well established suburb
   - No close to the river to have "views"
   - Parts are close to waterways that lead to storm surge flooding

Outline

Data

	Min	Max	Mean	Median	St.Dev
Sale Price (in 1000)	15.5	1250	191.77	161.50	129.44

Total number of Sales	13088	
Number of Months	233	
Number of Vacant Sales	3303	
Sample period	1991:5	2010:9

Land Component Characteristics

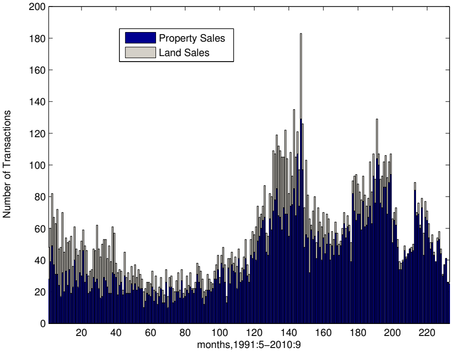
$$L_t = f(Land, Land^2, distances)$$

	Min	Max	Mean	Median	St.Dev
Land area (hectarea)	0.03	1.06	0.10	0.06	0.11
dist_coast (Km)	0.02	5.78	1.39	1.38	0.93
dist_waterway (Km)	0.01	0.86	0.27	0.25	0.16
dist_OffenIndus (Km)	0.18	8.38	2.87	2.27	1.83
dist_parks (Km)	0.01	0.98	0.13	0.11	0.11
dist_busStop (Km)	0.02	4.35	0.47	0.22	0.80
dist_Schools (Km)	0.01	6.55	0.65	0.32	1.09
dist_Shops (Km)	0.01	4.80	0.53	0.40	0.49
dist_BoatRamp (Km)	0.06	6.29	1.97	1.60	1.46

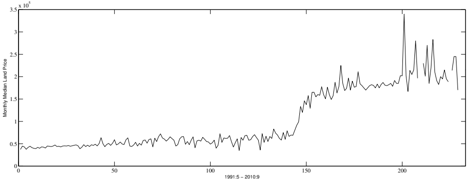
Structure Component Characteristics

$$S_t = f(Age, Age^2, Footprint, Footprint^2, Bath, Beds, Cars, Structure)$$

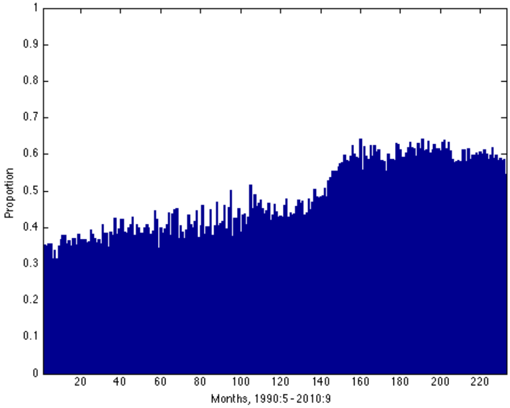
	Min	Max	Mean	Median	St.Dev
Structure=1	0.00	1.00	0.75	1.00	0.43
Age (years)	0.00	86.00	11.94	10.00	11.44
Structure Footprint (hectarea)	0.00	0.09	0.02	0.02	0.01
Number of Bathrooms	0.00	4.00	1.06	1.00	0.78
Number of Bedrooms	0.00	8.00	2.52	3.00	1.58
Number of Parking Spaces	0.00	5.00	1.39	1.00	1.12



Vacant Land Prices - Monthly Median -



PREDICTED LAND PROPORTION IN PROPERTY SALES



Outline

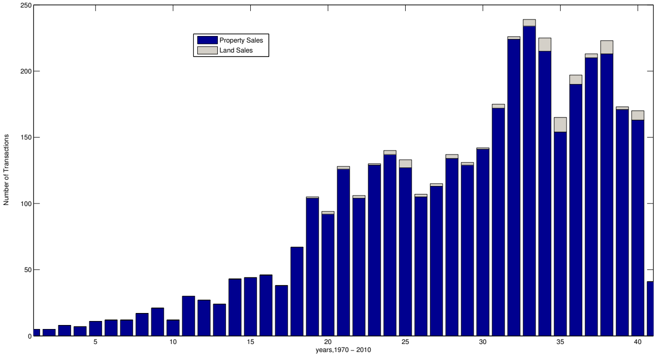
Data

	Min	Max	Mean	Median	St.Dev
Sale Price (in 1000)	2.60	4710.00	305.22	215.00	269.48
Total number of Sales	3944				
Number of Years	41				
Sample Period	1970	2010			

	Min	Max	Mean	Median	St.Dev
Land area (hectareas)	0.02	0.22	0.06	0.06	0.02
dist_waterway (Km)	0.01	1.62	0.57	0.53	0.38
dist_river (Km)	0.95	4.77	2.97	3.04	0.87
dist_industry (Km)	0.00	2.62	1.00	0.91	0.66
dist_park (Km)	0.01	0.56	0.18	0.16	0.12
dist_bikeway (Km)	0.01	1.51	0.57	0.56	0.35
dist_busstop (Km)	0.01	0.50	0.20	0.18	0.11
dist_TrainStn (Km)	0.01	3.17	1.38	1.40	0.82
dist_school (Km)	0.04	1.23	0.47	0.45	0.24
dist_shops (Km)	0.00	1.09	0.36	0.33	0.19
dist_CBD (Km)	2.46	5.77	3.97	3.97	0.82

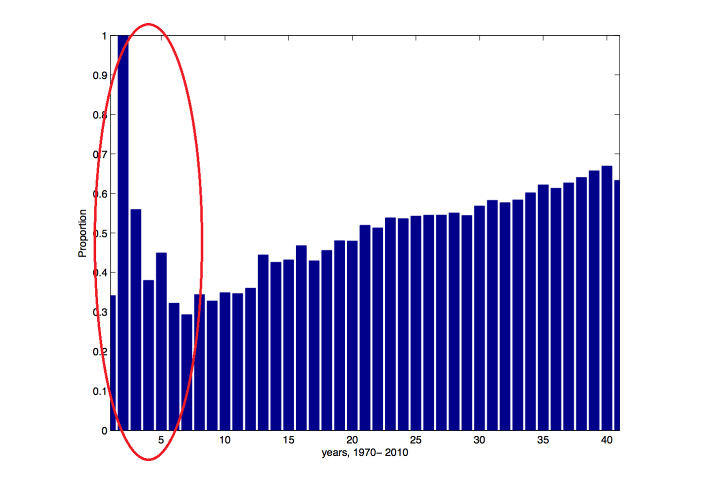
Structure Component Characteristics

	Min	Max	Mean	Median	St.Dev
Pre-War	0.00	1.00	0.49	0.00	0.50
War/Post War	0.00	1.00	0.37	0.00	0.48
Late 20th C	0.00	1.00	0.07	0.00	0.26
Contemporaneous	0.00	1.00	0.04	0.00	0.20
Structure=1	0.00	1.00	0.98	1.00	0.15
Structure footprint	0.00	0.10	0.02	0.02	0.01
Number of Levels	0.00	4.00	1.10	1.00	0.36
Number of Bathrooms	0.00	6.00	1.37	1.00	0.67
Number of Bedrooms	0.00	8.00	3.04	3.00	0.91
Number of Parking Spaces	0.00	8.00	1.66	2.00	0.78



Very few transactions in the earlier years

PREDICTED LAND PROPORTION IN PROPERTY SALES



Takes about six periods to settle.

Model vs Valuer - Properties sold in 2009

- $VE_i = \frac{\text{valuer's land valuation}_i}{\text{property sale price}_i}$

Month Sold	Median VE	# Properties
Jan-09	0.721	13
Feb-09	0.704	11
Mar-09	0.762	16
Apr-09	0.741	17
May-09	0.746	16
Jun-09	0.675	9
Jul-09	0.738	11
Aug-09	0.673	13
Sep-09	0.734	14
Oct-09	0.617	19
Nov-09	0.683	12
Dec-09	0.716	15
Median 2009	0.716	166

- Model Median for the 166 properties sold in 2009 = 0.669

Outline

- Used in Diewert et al. (2015). A shorter and earlier version was used by Färe et al. (2015).

	min	max	mean	median	stdev
Price (000 Euros)	70	550	182.260	160	71.316
Land Characteristics					
Land (sq mts)	70	1344	258.060	217	152.310
Structure Characteristics					
House (sq mts)	65	352	126.560	120	29.841
Age (years)	0	4	1.895	2	1.231
floors	1	6	2.878	3	0.478
rooms	2	10	4.730	5	0.874
Number of Transactions	3487				
Number of months	66	(2003:1	2008:6)		
The data were cleaned following Diewert et al (2015). See footnotes 11,12,13.					

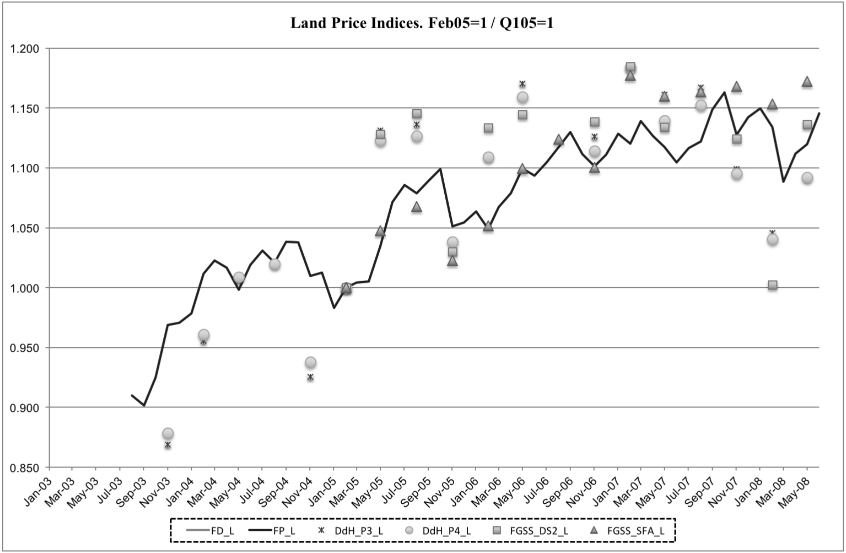
Outline

Price Indices Compared

	Model	Estimation	Label	Symbol
Diewert et al. (2015) Builder's Model with linear splines (*New Construction Index*)	Model3: land, house,age	2003:Q1 - 2008:Q2 quarter-by-quarter	DdH_PL3 (DdH_PS3)	
	Model4: Model 3 + other hedonic characteristics	2003:Q1 - 2008:Q2 quarter-by-quarter	DdH_PL4 (DdH_PS4)	
Färe et al (for structure uses SFA_L as exogenous index)	Model 4	2005:Q1 - 2008:Q2 quarter-by-quarter	FGCS_DS2_L (FGCS_DS2_S)	
	Model 4	2005:Q1 - 2008:Q2 **Distance Function Approach - whole sample**	FGCS_SFA_L (FGCS_SFA_S)	

Price Indices Compared (cont)

- Model Used here
  $Price = f(\text{land, house, age, rooms}, rooms^2, \text{floors}, floors^2)$
- Monthly 2003:1-2008:6. Estimation for time τ uses $t = 1, \ldots, \tau - 1, \tau$.
- Indices labels
  1. FP_L (FD_L)
  2. FP_S (FD_S)



Land Price Indices. Feb05=1 / Q105=1
1.200
1.150
1.100
1.050
1.000
0.950
0.900
0.850
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
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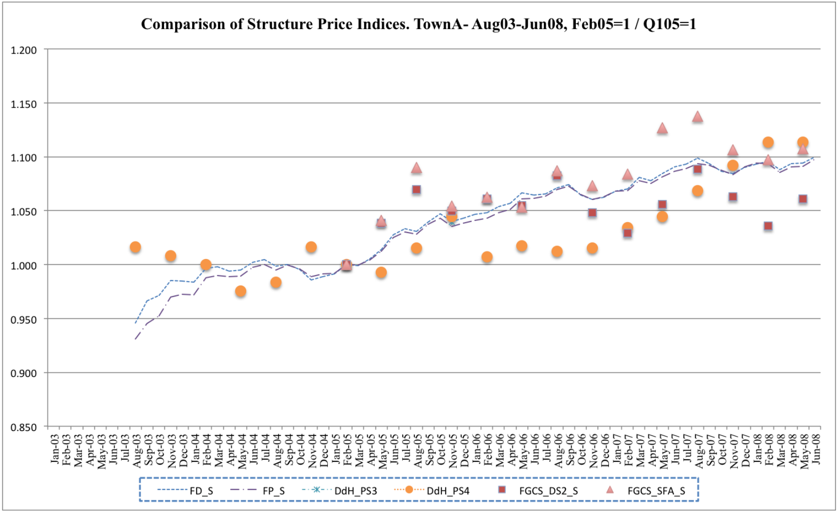
May-06
Jul-06
Sep-06
Nov-06
Jan-07
Mar-07
May-07
Jul-07
Sep-07
Nov-07
Jan-08
Mar-08
May-08
FD_L
FP_L
DdH_P3_L
DdH_P4_L
FGSS_DS2_L
FGSS_SFA_L



Comparison of Structure Price Indices. TownA- Aug03-Jun08, Feb05=1 / Q105=1
1.200
1.150
1.100
1.050
1.000
0.950
0.900
0.850
Jan-03 Feb-03 Mar-03 Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03 Dec-03 Jan-04 Feb-04 Mar-04 Apr-04 May-04 Jun-04 Jul-04 Aug-04 Sep-04 Oct-04 Nov-04 Dec-04 Jan-05 Feb-05 Mar-05 Apr-05 May-05 Jun-05 Jul-05 Aug-05 Sep-05 Oct-05 Nov-05 Dec-05 Jan-06 Feb-06 Mar-06 Apr-06 May-06 Jun-06 Jul-06 Aug-06 Sep-06 Oct-06 Nov-06 Dec-06 Jan-07 Feb-07 Mar-07 Apr-07 May-07 Jun-07 Jul-07 Aug-07 Sep-07 Oct-07 Nov-07 Dec-07 Jan-08 Feb-08 Mar-08 Apr-08 May-08 Jun-08
FD_S
FP_S
DdH_PS3
DdH_PS4
FGCS_DS2_S
FGCS_SFA_S

- An econometric model of the valuer's problem.
- Method combines
  - hedonic information on the land (including location) and structure -transaction level data
  - time-varying parameters model with a constrained covariance structure to separate the components using a dynamic identification
- No other information is used. Our estimates of the components are weighted sums of past and current information
- Fast computation algorithm.
- The decompositions obtained are reasonable and comparable to those made by valuers from the QLD state government.
- Fisher indices for the prices of the land and structure components are computed.
  - Indices are less volatile than DhH, but are able to pick up the turns in market conditions

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