Decoupling Land Values in Residential Property Prices

DISCUSSANT: M. B. REINSDORF

Authors: Alicia N. Rambaldi Ryan R. J. McAllister and Cameron S. Fletcher
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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)).
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)
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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,

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

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 \( w_{t-1} > w_{t-2} > w_{t-3} > \ldots \)
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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.

\[
y_t = Land_t + Struct_t + \epsilon_t
\]  

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.

\(\epsilon_t \sim N(0, \sigma^2)\)
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,

  \[ Land_t = f(X_t^L, \alpha_t^L) \]  

  \[ Struct_t = g(X_t^S, \alpha_t^S) \]  

where, $\alpha_t^c$ 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:

$$\text{Land}_t = X^L_t \alpha^L_t; \text{Struct}_t = X^S_t \alpha^S_t$$

with a filter updating of the form

$$\begin{align*}
\alpha^L_t &= \alpha^L_{t-1} + G^L_t \nu_t \\
\alpha^S_t &= \alpha^S_{t-1} + G^S_t \nu_t
\end{align*}$$

(5)

where,

$X^L_t$ are characteristics of the land (i.e., size and location), $X^S_t$ are characteristics of the structure (i.e., size, age)

$\alpha^c_t$, $c = \text{Land}, \text{Struct}$ measure willingness to pay for hedonic characteristics

$$\nu_t = y_t - X^L_t \tilde{\alpha}^L_{t-1} - X^S_t \tilde{\alpha}^S_{t-1}$$

vector of price prediction errors - for properties sold in in period $t$

$G^c_t$, $c = \text{Land, Struct}$, are functions of:

$X^L_t, X^S_t$,

covariance of $\nu_t$,

covariance of $\tilde{\alpha}_t = [\tilde{\alpha}^L_t, \tilde{\alpha}^L_t]$,

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 $\alpha_t^c$ is time-invariant
Estimation

- Only three parameters to estimate by maximum likelihood
  \( \psi = [\sigma^2, \delta_L, \delta_S] \)
    - maximise log-likelihood to estimate \( \sigma^2 \), using grid search for discount factors, \( \delta_L \) and \( \delta_S \)
- With \( \tilde{\psi} \) compute \( G^c_t, \alpha^c_t \) and \( \nu_t \) using modified filter algorithm
- Matlab code - runs in seconds.
- Can show that \( \hat{Land}_t = f(X^L_t | X^S_t) \) and \( \hat{Struct}_t = f(X^S_t | X^L_t) \)
The Fisher Plutocratic index is defined as:

\[
F^P_{(t-s),t} = \sqrt{L^P_{(t-s),t} P^P_{(t-s),t}}
\]  

where \( L^P_{t-s,t} \) and \( P^P_{t-s,t} \) are respectively the Laspeyres and Paasche index numbers,

\[
L^P_{(t-s),t} = \sum_{h=1}^{N_s} w^h_{(t-s)} \left( \frac{\hat{p}^L_t(x^L_{(t-s)})}{\hat{p}^L_{(t-s)}(x^L_{(t-s)})} \right);
\]

\[
P^P_{(t-s),t} = \left[ \sum_{h=1}^{N_t} w^h_{t} \left( \frac{\hat{p}^L_{(t-s)}(x^L_{t})}{\hat{p}^L_t(x^L_{t})} \right) \right]^{-1}
\]

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:

\[
w^h_t = \frac{P^h_t}{\sum_{n=1}^{N_t} P^n_t}
\]

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 \( w^h_t = 1/N_t \).
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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
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Data

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<th></th>
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<th>Median</th>
<th>St.Dev</th>
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<td>2010:9</td>
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## Land Component Characteristics

\[ L_t = f(Land, \text{Land}^2, \text{distances}) \]

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
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<th>Mean</th>
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<td>Land area (hectarea)</td>
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<td>1.06</td>
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<td>0.06</td>
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<td>dist_waterway (Km)</td>
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<td>0.86</td>
<td>0.27</td>
<td>0.25</td>
<td>0.16</td>
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<td>dist_OffenIndus (Km)</td>
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<td>8.38</td>
<td>2.87</td>
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<td>1.83</td>
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<td>0.11</td>
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<td>4.35</td>
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<td>0.22</td>
<td>0.80</td>
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<tr>
<td>dist_Schools (Km)</td>
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<td>6.55</td>
<td>0.65</td>
<td>0.32</td>
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<td>dist_Shops (Km)</td>
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<td>4.80</td>
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<td>6.29</td>
<td>1.97</td>
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<td>1.46</td>
</tr>
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</table>
Structure Component Characteristics

\[ S_t = f(Age, Age^2, Footprint, Footprint^2, Bath, Beds, Cars, Structure) \]

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
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<td>0.00</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
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<tr>
<td>Age (years)</td>
<td>0.00</td>
<td>86.00</td>
<td>11.94</td>
<td>10.00</td>
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<tr>
<td>Structure Footprint (hectarea)</td>
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<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
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<tr>
<td>Number of Bathrooms</td>
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<td>4.00</td>
<td>1.06</td>
<td>1.00</td>
<td>0.78</td>
</tr>
<tr>
<td>Number of Bedrooms</td>
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<td>2.52</td>
<td>3.00</td>
<td>1.58</td>
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<td>Number of Parking Spaces</td>
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<td>5.00</td>
<td>1.39</td>
<td>1.00</td>
<td>1.12</td>
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</table>
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<th>Max</th>
<th>Mean</th>
<th>Median</th>
<th>St.Dev</th>
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<tbody>
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<td>Number of Years</td>
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<td>Sample Period</td>
<td>1970</td>
<td>2010</td>
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## Land Component Characteristics

<table>
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<th>Max</th>
<th>Mean</th>
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<th>St.Dev</th>
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<tbody>
<tr>
<td>Land area (hectareas)</td>
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<td>0.57</td>
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<td>3.97</td>
<td>0.82</td>
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Structure Component Characteristics

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<td>Number of Bathrooms</td>
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<td>1.37</td>
<td>1.00</td>
<td>0.67</td>
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<tr>
<td>Number of Bedrooms</td>
<td>0.00</td>
<td>8.00</td>
<td>3.04</td>
<td>3.00</td>
<td>0.91</td>
</tr>
<tr>
<td>Number of Parking Spaces</td>
<td>0.00</td>
<td>8.00</td>
<td>1.66</td>
<td>2.00</td>
<td>0.78</td>
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</table>
Very few transactions in the earlier years
Takes about six periods to settle.
Model vs Valuer - Properties sold in 2009

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

<table>
<thead>
<tr>
<th>Month Sold</th>
<th>Median VE</th>
<th># Properties</th>
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<tr>
<td>Jan-09</td>
<td>0.721</td>
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<tr>
<td>Feb-09</td>
<td>0.704</td>
<td>11</td>
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<tr>
<td>Mar-09</td>
<td>0.762</td>
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<td>Apr-09</td>
<td>0.741</td>
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<td>May-09</td>
<td>0.746</td>
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<td>Jun-09</td>
<td>0.675</td>
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<td>Jul-09</td>
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<tr>
<td>Aug-09</td>
<td>0.673</td>
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<td>Sep-09</td>
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<tr>
<td>Oct-09</td>
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</tr>
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<td>Nov-09</td>
<td>0.683</td>
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</tr>
<tr>
<td>Dec-09</td>
<td>0.716</td>
<td>15</td>
</tr>
<tr>
<td><strong>Median 2009</strong></td>
<td><strong>0.716</strong></td>
<td><strong>166</strong></td>
</tr>
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Model Median for the 166 properties sold in 2009 = 0.669
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References
Used in Diewert et al. (2015). A shorter and earlier version was used by Färe et al. (2015).

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>max</th>
<th>mean</th>
<th>median</th>
<th>stdev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price (000 Euros)</strong></td>
<td>70</td>
<td>550</td>
<td>182.260</td>
<td>160</td>
<td>71.316</td>
</tr>
<tr>
<td><strong>Land Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land (sq mts)</td>
<td>70</td>
<td>1344</td>
<td>258.060</td>
<td>217</td>
<td>152.310</td>
</tr>
<tr>
<td><strong>Structure Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House (sq mts)</td>
<td>65</td>
<td>352</td>
<td>126.560</td>
<td>120</td>
<td>29.841</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0</td>
<td>4</td>
<td>1.895</td>
<td>2</td>
<td>1.231</td>
</tr>
<tr>
<td>floors</td>
<td>1</td>
<td>6</td>
<td>2.878</td>
<td>3</td>
<td>0.478</td>
</tr>
<tr>
<td>rooms</td>
<td>2</td>
<td>10</td>
<td>4.730</td>
<td>5</td>
<td>0.874</td>
</tr>
</tbody>
</table>

| 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

Introduction and Background

The Valuer’s Model
  Simple Behavioural Model

The Econometric Approach to the Decomposition
  Unobserved Components Approach

Price Indices

Decompositions - Empirical Estimates
  Model Estimation and Comparison to Valuer’s Estimates
  Bay Area - Monthly Data
  Brisbane Suburb - Annual Data

Price Indices - Empirical Evidence
  Town of A Data
    Town of A Indices

Discussion-Conclusions

References
<table>
<thead>
<tr>
<th>Model</th>
<th>Estimation</th>
<th>Label</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diewert et al. (2015)</strong>&lt;br&gt;Builder’s Model with linear splines <em>(New Construction Index)</em></td>
<td><strong>Model3</strong>: land, house, age</td>
<td>2003:Q1 - 2008:Q2 quarter-by-quarter</td>
<td>DdH_PL3 (DdH_PS3)</td>
</tr>
<tr>
<td><strong>Model4</strong>: Model 3 + other hedonic characteristics</td>
<td></td>
<td>2003:Q1 - 2008:Q2 quarter-by-quarter</td>
<td>DdH_PL4 (DdH_PS4)</td>
</tr>
<tr>
<td><strong>Färe et al (for structure uses SFA_L as exogenous index)</strong>&lt;br&gt;Model 4</td>
<td></td>
<td>2005:Q1 - 2008:Q2 quarter-by-quarter</td>
<td>FGCS_DS2_L (FGCS_DS2_S)</td>
</tr>
<tr>
<td><strong>Model 4</strong></td>
<td><strong>Model 4</strong></td>
<td>2005:Q1 - 2008:Q2 Distance Function Approach - whole sample</td>
<td>FGCS_SFA_L (FGCS_SFA_S)</td>
</tr>
</tbody>
</table>
Model Used here

\[ Price = f(\text{land, house, age, rooms, rooms}^2, \text{floors, floors}^2) \]

Monthly 2003:1-2008:6. Estimation for time \( \tau \) uses \( t = 1, \ldots, \tau - 1, \tau \).

Indices labels

1. FP_L (FD_L)
2. FP_S (FD_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


