

## **The Paris OECD-IMF Workshop on Real Estate Price Indexes: Conclusions and Future Directions**

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### **Abstract**

The paper summarizes the main ideas suggested in OECD-IMF Workshop on Real Estate Price Indexes which was held in Paris, November 6-7, 2006. The paper discusses possible uses and target indexes for real estate price indexes and notes that a major problem is that it is not possible to exactly match the quality of dwelling units over time due to the fact that the housing stock changes in quality due to renovations and depreciation. Four alternative methods for constructing real estate price indexes are discussed: the repeat sales model; the use of assessment information along with property sale information; stratification methods and hedonic methods. The paper notes that the typical hedonic regression method may suffer from specification bias and suggests a way forward. Problems with the user cost method for pricing the services of owner occupied housing are also discussed.

### **Journal of Economic Literature Classification Numbers**

C43, E31, R21.

### **Key Words**

Real estate price indexes; housing, index number theory; hedonic regression techniques; repeat sales method; system of national accounts; user costs; rental equivalence.

## **1. Introduction**

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<sup>1</sup> This paper is an extended written version of my Discussion at the Concluding Overview session of the OECD-IMF Workshop on Real Estate Price Indexes held in Paris, November 6-7, 2006. The financial assistance of the OECD and the Australian Research Council is gratefully acknowledged, as is the hospitality of the Centre for Applied Economic Research at the University of New South Wales. The author thanks Paul Armknecht, Stephan Arthur, David Fenwick, Jan de Haan, Johannes Hoffmann, Anne Laferrère, Marc Prud'homme, David Roberts, Mick Silver, Paul Schreyer and Kam Yu for helpful comments. None of the above individuals or organizations are responsible for any opinions expressed in this paper.

This paper highlights some of the themes that emerged from the OECD-IMF Workshop on Real Estate Price Indexes which was held in Paris, November 6-7, 2006.

Section 2 discusses the question: what are appropriate target indexes for Real Estate Prices? This section argues that the present System of National Accounts is a good starting point for a systematic framework for Real Estate Price indexes but the present SNA has to be augmented somewhat to meet the needs of economists who are interested in measuring consumption on a more comprehensive service flow basis and who are interested in measuring the productivity of the economy.

Section 3 notes the fundamental problem that makes the construction of constant quality real estate price indexes very difficult: namely depreciation and renovations to structures make the usual matched model methodology for constructing price indexes inapplicable.

Section 4 discusses four classes of methods that were suggested at the workshop to deal with the above problem and section 5 discusses some additional technical difficulties.

Section 6 discusses the problems raised by Verbrugge's (2006) contribution to the Workshop; i.e., why do user costs diverge so much from rents?

Finally, section 7 summarizes suggestions for moving the agenda forward.

## **2. What are Appropriate Target Indexes?**

There are many possible target real estate price indexes that could be constructed. Thus it is useful to consider alternative *uses* for real estate price indexes that were suggested at the workshop since these uses will largely determine what type of indexes should be constructed.

Fenwick (2006; 6) suggested the following list of possible uses for house price indexes:

- As a general macroeconomic indicator (of inflation);
- As an input into the measurement of consumer price inflation;
- As an element in the calculation of household (real) wealth and
- As a direct input into an analysis of mortgage lender's exposure to risk of default.

Arthur (2006) also suggested some (related) uses for real estate price indexes:

- Real estate price bubbles (and the subsequent collapses) have repeatedly been related to financial crises and thus it is important to measure these price bubbles accurately and in a way that is comparable across countries and
- Real estate price indexes are required for the proper conduct of monetary policy.

Fenwick also argued that various real estate price indexes are required for deflation purposes in the System of National Accounts:

“The primary focus of a national accountant seeking an appropriate deflator for national accounts will be different. Real estate appears in the National Accounts in several ways;

- the imputed rental value received by owner occupiers for buildings, as opposed to land, is part of household final consumption,
- the capital formation in buildings, again as opposed to land, is part of gross fixed capital formation, depreciation, and the measurement of the stock of fixed capital,
- and land values are an important part of the National stock of wealth.”

David Fenwick (2006; 7-8)

Fenwick (2006; 6) also argued that it would be useful to develop a coherent conceptual framework for an appropriate *family* of real estate price indexes<sup>2</sup> and he provided such a framework towards the end of his paper.<sup>3</sup>

Diewert, in his oral presentation to the Workshop, followed Fenwick and argued that in the first instance, real estate price statistics should serve the needs of the System of National Accounts. Why this conclusion?

The answer to this question is that (with one exception to be discussed later) the SNA provides a quantitative framework where value flows and stocks are systematically decomposed in an economically meaningful way into price and quantity (or volume) components. The resulting p’s and q’s are the basic building blocks which are used in virtually all macroeconomic models. Hence it seems important that price statisticians do their best to meet the deflation needs of the System of National Accounts.

Before the one major problem area with the present SNA is discussed, it will be useful to review a bit of basic economics. There are two basic paradigms or models in economics:

- Consumers or households maximizing utility subject to their budget constraints and
- Producers maximizing profits subject to their production function (or more generally, their technology) constraints.

There are one period “static” and many period “intertemporal” versions of the two models. However, for our purposes, it suffices to say that the SNA provides the necessary data to implement both models *except* that the SNA does not deal adequately with the consumption of consumer durables for applications to consumer models or the use of durable inputs in the producer context. The problem is the following one. When a consumer or producer purchases a good that provides services over a number of years, it is not appropriate to charge the entire purchase cost to the quarter or month when the durable is purchased: the purchase cost needs to be spread out over the useful life of the durable. However, with one exception, the SNA simply charges the entire cost of the

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<sup>2</sup> “It can be seen that user needs will vary and that in some instances, more than one measure of house price or real estate inflation may be required. It can also be seen that coherence between different measures and with other economic statistics is important and that achieving this will be especially difficult as statisticians are unlikely to have an ideal set of price indicators available to them.” David Fenwick (2006; 8).

<sup>3</sup> See Fenwick (2006; 8-11).

durable to the period of purchase.<sup>4</sup> This is not an appropriate treatment of durables for many economic purposes. Thus with respect to the household accounts, in addition to the usual *acquisitions approach* to consumer durables (which simply charges the entire purchase cost to the period of purchase), it is useful to have alternative measures of the service flows generated by household holdings of consumer durables. There are two alternative approaches to constructing such flow measures:

- An *imputed rent approach* which simply imputes market rental prices for the same type of service (if such prices are available) and
- A *user cost approach* which forms an estimate of what the cost would be of buying the durable at the beginning of the period, using the services of the good during the period and then selling it at the end of the period. This estimated cost also includes the interest cost that is associated with value of the capital that is tied up in the purchase of the durable.<sup>5</sup>

We will discuss the relative merits of the above two service flow methods for valuing housing services in section 6 below. For additional material on the various economic approaches to the treatment of durables and housing in particular, see Diewert (2002; 611-622), (2003), Verbrugge (2006) or Chapter 23, “Durables and User Costs”, in the International Labour Organization (ILO) Consumer Price Index Manual (2004).

On the producer side of the System of National Accounts, the service flows generated by durable inputs that are used to produce goods and services are buried in Gross Operating Surplus. Jorgenson and Griliches (1967) (1972) showed how gross operating surplus could be decomposed into price and quantity components using the user cost idea and their work led directly to the first national statistical agency productivity program; see the Bureau of Labor Statistics (1983).<sup>6</sup> Schreyer, Diewert and Harrison (2005) argued that this *productivity oriented approach to the System of National Accounts* could be regarded as a natural extension of the present SNA where the extended version provides a decomposition of a value flow (Gross Operating Surplus) into price and quantity (or volume) components.

We will argue below that if the SNA is expanded to exhibit the service flows that are associated with the household and production sectors’ purchases of durable goods, then the resulting *Durables Augmented System of National Accounts* (DASNA)<sup>7</sup> provides a natural framework for a family of real estate price indexes.

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<sup>4</sup> The one exception is residential housing, where estimates of the period by period flow of housing services are made in the SNA.

<sup>5</sup> The user cost idea can be traced back to Walras in 1874; see Walras (1954).

<sup>6</sup> The list of countries who now have official productivity programs includes the U.S., Canada, the UK, Australia, New Zealand and Switzerland. The EU KLEMS project is developing productivity accounts for many European countries using the Jorgenson and Griliches methodology, which is described in more detail in Schreyer (2001). For recent extensions and modifications, see Schreyer (2006).

<sup>7</sup> Such an accounting system is laid out in great detail and implemented for the U.S. by Jorgenson and Landefeld (2006).

In this augmented system of national accounts, household wealth and consumption will be measured in real and nominal terms. This will entail measures of the household sector's stock of residential wealth and it will be of interest to decompose this value measure into price and volume (or quantity) components. It will also be useful to decompose the residential housing stock aggregate into various subcomponents such as:

- by type of housing,
- by location or region,
- by the proportion of land and structures in the aggregate value,
- by age (in particular, new housing should be distinguished) and
- whether the residence is rented or owned.

Each of these subaggregates should be decomposed into price and volume components if possible. The DASNA will also require a measure of the flow of services from households' consumption of services from their long lived consumer durables, such as motor vehicles and owner occupied housing.<sup>8</sup> Thus it will be necessary to either implement the rental equivalence approach (as is currently recommended in the SNA) or the user cost approach (or both) to valuing the services of Owner Occupied Housing in this extended system of accounts.<sup>9</sup>

Turning now to the producer side of the DASNA, for productivity measurement purposes, we will want user costs for owned commercial, industrial and agricultural properties. In order to form wealth estimates, we will require estimates for the value of commercial, industrial and agricultural properties and decompositions of the values into price and volume components. The price components can be used as basic building blocks to form user costs for these various types of property. It will also be useful to decompose these business property stock aggregates into various subcomponents such as:

- by type of structure,
- by location or region,
- by the proportion of land and structures in the aggregate value,
- by age (in particular, new structures should be distinguished) and
- whether the structure is rented or owned.

If we turn back to the list of uses for real estate price indexes suggested by Fenwick and Arthur earlier in this section, it can be seen that if we had all of the price indexes for implementing the DASNA as suggested above, then virtually all of the user needs could be met by this family of national accounts type real estate price indexes. Thus it seems to me that the Durables Augmented SNA is a natural framework for the development of real estate price indexes that would meet user needs.

We turn now to a discussion of the many technical issues that arise when trying to construct a property price index.

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<sup>8</sup> For short lived household durables, it is not worth the bother of capitalizing these stocks and so the usual acquisitions approach will suffice for these assets.

<sup>9</sup> We will return to this topic in section 6 below.

### 3. The Failure of the Traditional Matched Model Methodology in the Real Estate Context

Consider the problems involved in constructing a constant quality price index for say a class of residential dwelling units or for a class of business structures. The starting point for constructing any price index between two time periods is to collect prices on exactly the same product or item for the two time periods under consideration; this is the standard *matched model* methodology.<sup>10</sup>

The *fundamental problem* that price statisticians face when attempting to construct a real estate price index is that *exact matching of properties over time is not possible* for two reasons:

- The property depreciates over time (*the depreciation problem*) and
- The property may have had major repairs, additions or remodeling done to it between the two time periods under consideration (*the renovations problem*).

Because of the above two problems, constructing constant quality real estate price indexes cannot be a straightforward matter; some form of imputation or indirect estimation will be required.

A third problem that faces many European countries is the *problem of low turnover of properties*; i.e., if the sales of properties are very infrequent, then even if the depreciation and renovations problems could be solved, there would still be a problem in constructing a satisfactory property price index because of the low incidence of resales.<sup>11</sup>

A fourth problem should be mentioned at this point. For some purposes, it is desirable to decompose the real estate price index into two separate constant quality components:

- A component that measures the change in the price of the structure and
- A component that measures the change in the price of the underlying land.

In the following section, we will look at some of the methods that were suggested by conference participants to construct constant quality real estate price indexes for the land and structures taken together. The problem of decomposing a real estate price index into its structure and land components will be deferred until section 5 below.

## 4. Suggested Methods for Constructing Constant Quality Real Estate Price Indexes

### 4.1 The Repeat Sales Method

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<sup>10</sup> For a detailed description of how this methodology works, see Chapter 20, “Elementary Indices”, in the ILO (2004).

<sup>11</sup> Related problems are that the mix of transactions can change over time and in fact entirely new types of housing can enter the market.

The *repeat sales approach* is due to Bailey, Muth and Nourse (1963), who saw their procedure as a generalization of the *chained matched model methodology* that was used by the early pioneers in the construction of real estate price indexes like Wyngarden (1927) and Wenzlick (1952). We will not describe the technical details of the method but just note that the method uses information on properties which trade on the market more than once over the sample period.<sup>12</sup> By utilizing information on “identical” properties that trade more than one period, the repeat sales method attempts to hold the quality of the properties constant over time.

We now discuss some of the advantages and disadvantages of the repeat sales method.<sup>13</sup>

The *main advantages* of the repeat sales model are:

- The availability of source data from administrative records on the resale of the same property so that no imputations are involved and
- Reproducibility of the results; i.e., different statisticians given the same data on the sales of housing units will come up with the same estimate of quality adjusted price change.<sup>14</sup>

The *main disadvantages* of the repeat sales model are:

- It does not use all of the available information on property sales; it uses only information on units that have sold more than once during the sample period.<sup>15</sup>

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<sup>12</sup> See Case and Shiller (1989) and Diewert (2003; 31-39) for detailed technical descriptions of the method. Diewert showed how the repeat sales method is related to Summers’ (1973) country product dummy model used in international price comparisons and the product dummy variable hedonic regression model proposed by Aizcorbe, Corrado and Doms (2001).

<sup>13</sup> Throughout this section, we will discuss the relative merits of the different methods that have been suggested for constructing property price indexes. For a similar (and perhaps more comprehensive) discussion, see Hoffmann and Lorenz (2006; 2-6).

<sup>14</sup> Hedonic regression models suffer from a reproducibility problem; i.e., different statisticians will use different characteristics variables, use different functional forms and make different stochastic specifications, possibly leading to quite different results. However, the repeat sales model is not as reproducible in practice as indicated in the main text because in some variants of the method, houses that are “flipped” (sold very rapidly) and houses that have not sold for long periods are excluded from the regressions. The exact method for excluding these observations may vary from time to time leading to a lack of reproducibility.

<sup>15</sup> Some of the papers presented at the workshop suggested that the repeat sales method might lead to estimates of price change that were biased upwards, since often sellers of properties undertake major renovations and repairs just before putting their properties on the market, leading to a lack of comparability of the unit from its previous sale. “The repeat sales method does not entirely adjust for changes in quality of the dwellings. If a dwelling undergoes a major renovation or even an extension between two transaction moments, the repeat sales method will not account for this. The last transaction price may in that case be too high, which results in an overestimation of the index.” Erna van der Wal, Dick ter Steege and Bert Kroese (2006; 3). “Research has suggested that appreciation rates for houses that sell may not be the same as appreciation rates for the rest of the housing stock.” Andrew Leventis (2006; 9). Leventis cites Stephens, Li, Lekkas, Abraham, Calhoun and Kimner (2005) on this point. Finally, Gudnason and Jonsdottir made the following observations on the method: “The problem with this method is the risk for bias; e.g., when major renovation and other changes have been made on the house which increases the quality or if the wear of the house has been high, causing a decrease in the quality. Such changes are not

- It cannot deal adequately with depreciation of the dwelling unit or structure.
- It cannot deal adequately with units that have undergone major repairs or renovations.<sup>16</sup> Conversely, a general hedonic regression model for housing or structures can adjust for the effects of renovations and extensions if (real) expenditures on renovations and extensions are known at the time of sale (or rental).<sup>17</sup>
- The method cannot be used if indexes are required for very fine classifications of the type of property due to a lack of observations. In particular, if monthly property price indexes are required, the method may fail due to a lack of market sales for smaller categories of property.
- In principle, estimates for past price change obtained by the repeat sales method should be updated as new transaction information becomes available.<sup>18</sup> Thus the Repeat Sales property price index is subject to never ending revision.

We turn now to another class of methods suggested by workshop participants in order to form constant quality property price indexes.

#### 4.2 The Use of Assessment Information

Most countries tax real estate property. Hence, most countries have some sort of official valuation office that provides periodic appraisals of all taxable real estate property. The paper by van der Wal, ter Steege and Kroese (2006) presented at the Workshop describes how Statistics Netherlands uses appraisal information in order to construct a property price index. In particular, the *SPAR (Sales Price Appraisal Ratio) Method* is described as follows:<sup>19</sup>

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captured by this method. In Iceland, this method cannot be used because the number of housing transactions are too few and thus there are not enough repeated sales to be able to calculate the repeated sales index.” Rosmundur Gudnason and Guorun Jonsdottir (2006; 2).

<sup>16</sup> Case and Shiller (1989) used a variant of the repeat sales method using US data on house sales in four major cities over the years 1970-1986. They attempted to deal with the depreciation and renovation problems as follows: “The tapes contain actual sales prices and other information about the homes. We extracted from the tapes for each city a file of data on houses sold twice for which there was no apparent quality change and for which conventional mortgages applied.” Karl E. Case and Robert J. Shiller (1989; 125-126). It is sometimes argued that renovations are approximately equal to depreciation. While this may be true in the aggregate, it certainly is not true for individual dwelling units because over time, many units are demolished.

<sup>17</sup> However, usually information on maintenance and renovation expenditures is not available in the context of estimating a hedonic regression model for housing. Malpezzi, Ozanne and Thibodeau (1987;375-6) comment on this problem as follows: “If all units are identically constructed, inflation is absent, and the rate of maintenance and repair expenditures is the same for all units, then precise measurement of the rate of depreciation is possible by observing the value or rent of two or more units of different ages. ... To accurately estimate the effects of aging on values and rents, it is necessary to control for inflation, quality differences in housing units, and location. The hedonic technique controls for differences in dwelling quality and inflation rates but cannot control for most differences in maintenance (except to the extent that they are correlated with location).”

<sup>18</sup> “Another drawback on the RS method is the fact that previously published index numbers will be revised when new data are added to the sample.” Erna van der Wal, Dick ter Steege and Bert Kroese (2006; 3).

<sup>19</sup> van der Wal, ter Steege and Kroese (2006; 3) noted that this method is described in more detail in Bourassa, Hoesli and Sun (2006). The conference presentation by Statistics Denmark indicated that a variant of this method is also used in Denmark. Jan de Haan brought to my attention that a much more

“This method has been used in New Zealand since the early 1960s. It also uses *matched pairs*, but unlike the Repeat Sales method, the SPAR method relies on nearly all transactions that have occurred in a given housing market, and hence should be less prone to sample selection bias. The first measure in each pair is the official government appraisal of the property, while the second measure is the matching transaction price. The ratio of the sale price and the appraisal of all sold dwellings in the base period,  $t = 0$ , serves as the denominator. The numerator is the ratio of the selling price of the reference period,  $t = t$ , and the appraisal of the base period of all dwellings that have been sold in the reference period.” Erna van der Wal, Dick ter Steege and Bert Kroese (2006; 3).

We will follow the example of van der Wal, ter Steege and Kroese and describe the SPAR method algebraically. Denote the number of sales of a certain type of real estate in the base period by  $N(0)$ , let the sales prices be denoted as  $[S_1^0, S_2^0, \dots, S_{N(0)}^0] \equiv S^0$  and denote the corresponding official appraisal prices as  $[A_1^{00}, A_2^{00}, \dots, A_{N(0)}^{00}] \equiv A^{00}$ . Similarly, denote the number of sales of the same type of property in the current period by  $N(t)$ , let the sales prices be denoted as  $[S_1^t, S_2^t, \dots, S_{N(t)}^t] \equiv S^t$  and denote the corresponding official appraisal prices in the base period as  $[A_1^{0t}, A_2^{0t}, \dots, A_{N(t)}^{0t}] \equiv A^{0t}$ . The *value weighted SPAR index* defined by van der Wal, ter Steege and Kroese (2006; 4) in our notation is defined as follows:

$$(1) P_{\text{DSPAR}}(S^0, S^t, A^{00}, A^{0t}) \equiv \left[ \frac{\sum_{i=1}^{N(t)} S_i^t / \sum_{i=1}^{N(t)} A_i^{0t}}{\sum_{n=1}^{N(0)} S_n^0 / \sum_{n=1}^{N(0)} A_n^{00}} \right].$$

We have labeled the index defined by (1) by using the notation  $P_{\text{DSPAR}}$  where the D stands for Dutot, since the index formula on the right hand side of (1) is closely related to the Dutot formula that occurs in elementary index number theory.<sup>20</sup>

What is the intuitive justification for formula (1)? One way to justify (1) is to suppose that the value  $S_n^0$  for each property transaction in period 0 is equal to a period 0 common price level for the type of property under consideration,  $P^0$  say, times a quality adjustment factor,  $Q_n^0$  say, so that:

$$(2) S_n^0 = P^0 Q_n^0 ; \quad n = 1, 2, \dots, N(0).$$

Next, we assume that the period 0 assessed value for transacted property  $n$ ,  $A_n^{00}$ , is equal to the common price level  $P^0$  times the quality adjustment factor  $Q_n^0$  times an independently distributed error term, which we write as  $1 + \varepsilon_n^{00}$ , where it is likely that the expected value for each of the error terms is 0.<sup>21</sup> Thus we have

$$(3) A_n^{00} = P^0 Q_n^0 (1 + \varepsilon_n^{00}) ; \quad n = 1, 2, \dots, N(0)$$

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comprehensive analysis of the SPAR method (similar in some respects to the analysis in this section) may be found in de Haan, van der Wal, ter Steege and de Vries (2006).

<sup>20</sup> If the term  $\sum_{n=1}^{N(0)} S_n^0 / \sum_{k=1}^{N(0)} A_k^{00}$  on the right hand side of (1) is equal to 1, then the index reduces to a Dutot index. For the properties of Dutot indexes, see Chapter 20, “Elementary Indices”, in ILO (2004) or IMF (2004).

<sup>21</sup> This stochastic specification reflects the fact that the errors are more likely to be multiplicative rather than additive.

with the error terms having zero expectations; i.e.:

$$(4) E \varepsilon_n^{00} = 0 ; \quad n = 1, 2, \dots, N(0).$$

Turning now to a model for the period t property price transactions, we suppose that the value  $S_n^t$  for each property transaction in period t is equal to a period t common price level for the type of property under consideration,  $P^t$  say, times a quality adjustment factor,  $Q_n^t$  say, so that:

$$(5) S_i^t = P^t Q_i^t ; \quad i = 1, 2, \dots, N(t).$$

Next, we assume that the period 0 assessed value for transacted property i in period t,  $A_i^{0t}$ , is equal to the period 0 price level  $P^0$  times the quality adjustment factor  $Q_i^t$  times an independently distributed error term, which we write as  $1 + \varepsilon_i^{0t}$ .<sup>22</sup> Thus we have:

$$(6) A_i^{0t} = P^0 Q_i^t (1 + \varepsilon_i^{0t}) ; \quad i = 1, 2, \dots, N(t).$$

Our goal is to obtain an estimator for the level of property prices in period t relative to period 0, which is  $P^t/P^0$ . Define the share of transacted property n in period 0 to the total value of properties transacted in period 0,  $s_n^0$ , as follows:

$$(7) s_n^0 \equiv S_n^0 / \sum_{k=1}^{N(0)} S_k^0 ; \quad n = 1, 2, \dots, N(0).$$

Similarly, define the share of transacted property i in period t to the total value of properties transacted in period t,  $s_i^t$ , as follows:

$$(8) s_i^t \equiv S_i^t / \sum_{k=1}^{N(t)} S_k^t ; \quad i = 1, 2, \dots, N(t).$$

Now substitute (2)-(6) into definition (1), use definitions (7) and (8), and we obtain the following expression for the Dutot type SPAR price index:

$$(9) P_{\text{DSPAR}}(S^0, S^t, A^{00}, A^{0t}) \\ = [\sum_{i=1}^{N(t)} P^t Q_i^t / \sum_{i=1}^{N(t)} P^0 Q_i^t (1 + \varepsilon_i^{0t})] / [\sum_{n=1}^{N(0)} P^0 Q_n^0 / \sum_{n=1}^{N(0)} P^0 Q_n^0 (1 + \varepsilon_n^{00})] \\ = [P^t/P^0] [1 + \sum_{k=1}^{N(0)} s_n^0 \varepsilon_n^{00}] / [1 + \sum_{n=1}^{N(t)} s_n^t \varepsilon_n^{0t}] .$$

Thus the Dutot type SPAR index will be unbiased for the “true” property price index,  $P^t/P^0$ , provided that the share weighted average of the period 0 and t quality adjustment errors are equal to zero; i.e., there will be no bias if

$$(10) \sum_{n=1}^{N(0)} s_n^0 \varepsilon_n^{00} = 0 \text{ and}$$

$$(11) \sum_{n=1}^{N(t)} s_n^t \varepsilon_n^{0t} = 0 .$$

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<sup>22</sup> It is no longer likely that the expected value of the error term  $\varepsilon_i^{0t}$  is equal to 0 since the base period assessments cannot pick up any depreciation and renovation biases that might have occurred between periods 0 and t.

It is likely that the weighted sum of errors in period 0 is equal to zero (at least approximately) because it is likely that the official assessed values for period 0 are approximately equal to the market transaction values in the same period; i.e., it is likely that (10) is at least approximately satisfied. However, it is not so likely that (11) would be satisfied since the period 0 assessed values will not reflect depreciation and renovations done between periods 0 and t. If the economy is growing strongly, then it is likely that the value of renovations will exceed the value of depreciation between periods 0 and t and hence the error terms  $\varepsilon_i^{0t}$  will tend to be less than 0 and  $P_{\text{DSPAR}}(S^0, S^t, A^{00}, A^{0t})$  will be biased upwards. On the other hand, if there is little growth (or a declining population), then it is likely that the value of renovations will be less than the value of depreciation between periods 0 and t and hence the error terms  $\varepsilon_i^{0t}$  will tend to be greater than 0 and  $P_{\text{DSPAR}}(S^0, S^t, A^{00}, A^{0t})$  will be biased downwards.

Variants of the Dutot type SPAR index can be defined; i.e., *the equal weighted SPAR index* defined by van der Wal, ter Steege and Kroese (2006; 4) in our notation is defined as follows:

$$\begin{aligned}
 (12) \quad P_{\text{CSPAR}}(S^0, S^t, A^{00}, A^{0t}) &\equiv \left[ \sum_{i=1}^{N(t)} (S_i^t / A_i^{0t}) / N(t) \right] / \left[ \sum_{n=1}^{N(0)} (S_n^0 / A_n^{00}) / N(0) \right] \\
 &= \left[ \sum_{i=1}^{N(t)} \{P^t Q_i^t / P^0 Q_i^0 (1 + \varepsilon_i^{0t})\} / N(t) \right] / \left[ \sum_{n=1}^{N(0)} \{P^0 Q_n^0 / P^0 Q_n^0 (1 + \varepsilon_n^{00})\} / N(0) \right] \\
 &\quad \text{using (2)-(6)} \\
 &= [P^t / P^0] \left[ \sum_{i=1}^{N(t)} (1 + \varepsilon_i^{0t})^{-1} / N(t) \right] / \left[ \sum_{n=1}^{N(0)} (1 + \varepsilon_n^{00})^{-1} / N(0) \right].
 \end{aligned}$$

We have labeled the index as  $P_{\text{CSPAR}}$  since looking at the first line of (12), it can be seen that the index is a ratio of two equally weighted indexes of price relatives; i.e., they are a ratio of two Carli indexes.<sup>23</sup> By looking at (12), it can be seen that if all of the error terms  $\varepsilon_i^{0t}$  and  $\varepsilon_i^{00}$  are equal to zero, then  $P_{\text{CSPAR}}(S^0, S^t, A^{00}, A^{0t})$  will be equal to the target index,  $P^t / P^0$ . Of course, it is much more likely that the period 0 error terms,  $\varepsilon_i^{00}$ , are close to zero than the period t terms,  $\varepsilon_i^{0t}$ . If in fact all of the period 0 error terms are equal to 0, then it can be seen that  $S_n^0 = A_n^{00}$  for all n and  $P_C$  reduces to the ordinary Carli index,  $\sum_{i=1}^{N(0)} (S_i^t / A_i^{0t}) / N(t)$ , which is known to be biased upwards.<sup>24</sup>

The last equation in (12) gives us an expression that could be helpful in determining the bias in this Carli type SPAR index in the general case of errors in both periods. However, it proves to be useful to approximate the reciprocal function,  $f(\varepsilon) \equiv (1 + \varepsilon)^{-1}$ , by the following second order Taylor series approximation around  $\varepsilon = 0$ :

$$\begin{aligned}
 (13) \quad f(\varepsilon) &\equiv (1 + \varepsilon)^{-1} \\
 &\approx 1 - \varepsilon + \varepsilon^2.
 \end{aligned}$$

Substituting (13) into the last line of (12), we find that the Carli type SPAR index is approximately equal to:

<sup>23</sup> For the properties of Carli indexes, see Chapter 20, "Elementary Indices", in ILO (2004).

<sup>24</sup> See Chapter 20, "Elementary Indices", in ILO (2004).

$$\begin{aligned}
(14) \quad P_{\text{CSPAR}}(S^0, S^t, A^{00}, A^{0t}) & \\
& \approx [P^t/P^0] [\sum_{i=1}^{N(t)} (1 - \varepsilon_i^{0t} + [\varepsilon_i^{0t}]^2)/N(t)] / [\sum_{n=1}^{N(0)} (1 - \varepsilon_n^{00} + [\varepsilon_n^{00}]^2)/N(0)] \\
& = [P^t/P^0] [1 + \{\sum_{i=1}^{N(t)} (-\varepsilon_i^{0t} + [\varepsilon_i^{0t}]^2)\}/N(t)] / [1 + \{\sum_{n=1}^{N(0)} (-\varepsilon_n^{00} + [\varepsilon_n^{00}]^2)\}/N(0)] \\
& \approx [P^t/P^0] [1 + \{\sum_{i=1}^{N(t)} (-\varepsilon_i^{0t} + [\varepsilon_i^{0t}]^2)\}/N(t)] / [1 + \sum_{n=1}^{N(0)} [\varepsilon_n^{00}]^2/N(0)]
\end{aligned}$$

where the last approximation follows from the (likely) assumption that

$$(15) \quad \sum_{n=1}^{N(0)} \varepsilon_n^{00} = 0 ;$$

i.e., that the sum of the assessment measurement errors in period 0 is zero. Now we can use the last line in (14) in order to assess the likely size of the bias in  $P_{\text{CSPAR}}$ . If the economy is growing strongly, then it is likely that the value of renovations will exceed the value of depreciation between periods 0 and  $t$  and hence the error terms  $\varepsilon_i^{0t}$  will tend to be less than 0 so that  $\sum_{i=1}^{N(t)} -\varepsilon_i^{0t}$  will be positive. The terms  $\sum_{i=1}^{N(t)} [\varepsilon_i^{0t}]^2/N(t)$  and  $\sum_{n=1}^{N(0)} [\varepsilon_n^{00}]^2/N(0)$  will both be positive but the period  $t$  squared errors will be much larger than the period 0 squared errors so overall,  $P_{\text{CSPAR}}(S^0, S^t, A^{00}, A^{0t})$  is likely to have a strong upward bias. On the other hand, if there is little growth (or a declining population), then the upward bias is likely to be smaller but an upward bias is still likely because the terms  $\sum_{i=1}^{N(t)} [\varepsilon_i^{0t}]^2/N(t)$  are likely to be very much larger than the terms  $-\sum_{i=1}^{N(t)} \varepsilon_i^{0t}/N(t)$  and  $\sum_{n=1}^{N(0)} [\varepsilon_n^{00}]^2/N(0)$ .

What about the relative sizes of the bias in the Dutot SPAR formula defined by the last line in (9) versus the Carli SPAR formula defined by the last line in (14)? Assuming that (10) holds and using a second order approximation analogous to (13) for  $[1 + \sum_{k=1}^{N(t)} s_n^t \varepsilon_n^{0t}]^{-1}$ , we obtain the following approximation for the Dutot type SPAR formula:

$$\begin{aligned}
(16) \quad P_{\text{DSPAR}}(S^0, S^t, A^{00}, A^{0t}) & \\
& \approx [P^t/P^0] / [1 + \sum_{n=1}^{N(t)} s_n^t \varepsilon_n^{0t}] \\
& \approx [P^t/P^0] \{1 - \sum_{n=1}^{N(t)} s_n^t \varepsilon_n^{0t} + [\sum_{k=1}^{N(t)} s_n^t \varepsilon_n^{0t}]^2\}.
\end{aligned}$$

Comparing (14) with (16), it can be seen that the upward bias in the Carli type index will generally be *much greater* than the corresponding bias in the Dutot type index, since the sum of the individual period  $t$  errors divided by the number of observations,  $\sum_{i=1}^{N(t)} [\varepsilon_i^{0t}]^2/N(t)$ , will usually be very much greater than the square of the period  $t$  weighted sum of errors,  $[\sum_{n=1}^{N(t)} s_n^t \varepsilon_n^{0t}]^2$ .

It is evident that instead of using arithmetic averages of price relatives as in the Carli type formula (12), geometric averages could be used, leading to the following *Jevons*<sup>25</sup> type SPAR index:

$$\begin{aligned}
(17) \quad P_{\text{JSPAR}}(S^0, S^t, A^{00}, A^{0t}) & \equiv [\prod_{i=1}^{N(t)} (S_i^t/A_i^{0t})]^{1/N(t)} / [\prod_{n=1}^{N(0)} (S_n^0/A_n^{00})]^{1/N(0)} \\
& = [\prod_{i=1}^{N(t)} \{P^t Q_i^t / P^0 Q_i^t (1 + \varepsilon_i^{0t})\}]^{1/N(t)} / [\prod_{n=1}^{N(0)} \{P^0 Q_n^0 / P^0 Q_n^0 (1 + \varepsilon_n^{00})\}]^{1/N(0)}
\end{aligned}$$

<sup>25</sup> For the properties of Jevons indexes, see Chapter 20, "Elementary Indices", in the ILO (2004) Manual.

$$= [P^t/P^0] \left[ \prod_{n=1}^{N(0)} (1+\varepsilon_n^{00}) \right]^{1/N(0)} / \left[ \prod_{i=1}^{N(t)} (1+\varepsilon_i^{0t}) \right]^{1/N(t)}.$$

using (2)-(6)

Under the assumption that there are no systematic appraisal errors in period 0 so that (4) is satisfied, we can assume that  $\prod_{n=1}^{N(0)} (1+\varepsilon_n^{00})$  is close to one but if the value of renovations between periods 0 and t exceeds the value of depreciation, it is likely that  $\prod_{i=1}^{N(t)} (1+\varepsilon_i^{0t})$  is less than one and hence  $P_{JSPAR}(S^0, S^t, A^{00}, A^{0t})$  will have an upward bias.<sup>26</sup>

It is evident that it is not really necessary to have the denominator terms in the right hand sides of definitions (1), (12) and (17) above, provided that the assessments are reasonably close to market values in the base period. Thus define the (regular) *Dutot, Carli and Jevons Market Value to Appraisal indexes* as follows:

$$(18) P_D(S^t, A^{0t}) \equiv \left[ \frac{\sum_{i=1}^{N(t)} S_i^t}{\sum_{i=1}^{N(t)} A_i^{0t}} \right];$$

$$(19) P_C(S^t, A^{0t}) \equiv \left[ \frac{\sum_{i=1}^{N(t)} (S_i^t/A_i^{0t})}{N(t)} \right];$$

$$(20) P_J(S^t, A^{0t}) \equiv \left[ \prod_{i=1}^{N(t)} (S_i^t/A_i^{0t}) \right]^{1/N(t)}.$$

Using the material in Chapter 20 of the *ILO CPI Manual* (2004), it can be shown that the Jevons index  $P_J(S^t, A^{0t})$  is always strictly less than the corresponding Carli index  $P_C(S^t, A^{0t})$ , unless all of the ratios  $S_i^t/A_i^{0t}$  are equal to the same number, in which case the indexes are equal to each other. It is also shown in the *ILO Manual* that the Dutot index will normally be fairly close to the corresponding Jevons index.<sup>27</sup>

None of the six index number formula discussed above are completely satisfactory because none of these methods can deal with the depreciation and renovations problem. However, if exogenous adjustments can be made to the indexes that make some sort of “average” adjustment to the index for renovations and depreciation, then appraisal methods become quite attractive. If appraisals in the base period are known to be reasonably accurate, then I would vote for the ordinary Jevons index,  $P_J(S^t, A^{0t})$ , defined by (20). If the appraisals in the base period are known to have a systematic bias, then the Jevons type SPAR index defined by (17),  $P_{JSPAR}(S^0, S^t, A^{00}, A^{0t})$ , seems to be the most attractive index.<sup>28</sup>

It is useful to discuss the merits of the above appraisal methods compared to other methods for constructing real estate price indexes.

The *main advantages* of methods that rely on assessment information in the base period and sales information in the current period are:

<sup>26</sup> Using second order Taylor series approximation techniques, it can be shown that the upward bias in the Jevons type SPAR index will be less than in the corresponding Carli type SPAR index.

<sup>27</sup> The Manual does not recommend the use of the Carli formula since it fails the time reversal test with an upward bias.

<sup>28</sup> These indexes should be further adjusted to take into account depreciation and renovations bias.

- The source data on assessment and sales are usually available from administrative records.
- These methods are reproducible conditional on the assessment information; i.e., different statisticians given the same data on the sales of housing units and the same base period assessment information will come up with the same estimate of quality adjusted price change.
- The assessment methods use much more information than the repeat sales method and hence there are fewer problems due to sparse data.
- Information on housing or structure characteristics is not required in order to implement this method.

The *main disadvantages* of the assessment methods discussed above are:

- They cannot deal adequately with depreciation of the dwelling units or structures.
- They cannot deal adequately with units that have undergone major repairs or renovations.
- These methods are entirely dependent on the quality of the base period assessment information. How exactly were the base period assessments determined? Were hedonic regression methods used? Were comparable property methods used?<sup>29</sup> How can we be certain that the quality of these base period assessments is satisfactory?<sup>30</sup>
- The methods discussed above do not deal with weighting problems.<sup>31</sup>
- If information on housing characteristics is not available, then the method can be used to form only a single index. However, in most countries, the rate of change in real estate prices is not constant across locations<sup>32</sup> and type of housing and so it is useful to be able to calculate more than one real estate price index.

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<sup>29</sup> Leventis (2006) discussed some of the problems with U.S. private sector assessment techniques when he discussed the work of Chinloy, Cho and Megbolugbe (1997) as follows: “Using a sample of 1993 purchase price data for which they also had the appraisal information, they compared purchase prices against appraisals to determine whether there were systematic differences. They estimated an upward bias of two percent and found that appraisals exceeded purchase price in approximately 60 percent of the cases. ... That appraisers ‘extrapolate’ valuations from recent results and have a vested interest in ensuring that their valuations appear reasonable (and perhaps consistent) to the originators suggest that the volatility of appraised values may be lower. At the same time, the authors believe that the appraisals’ reliance on a small number of comparables ‘almost surely’ leads to ‘more volatility than marketwide prices’. Andrew Leventis (2006; 5-6).

<sup>30</sup> If the assessments are used for taxation purposes and they are supposed to be based on market valuations, then the assessed values cannot be too far off the mark since the government has an incentive to make the assessments as large as possible (to maximize tax revenue) and taxpayers have the opposite incentive to have the assessments as small as possible.

<sup>31</sup> This is not really a major problem since the base period assessment information can be used to obtain satisfactory weights. When a new official assessment takes place, superlative indexes can be formed between any two consecutive assessment periods and interpolation techniques can be used to form approximate weights for all intervening periods. For descriptions of superlative indexes and their properties, see Diewert (1976) (1978) or Chapters 15-20 of ILO (2004).

<sup>32</sup> The paper presented by Girouard, Kennedy, van den Noord and André (2006; 26) showed that there are regional differences in the rate of housing price change. This paper also showed that real estate bubbles were quite common in many OECD countries. In many countries, bubbles lead to differential rates of housing price increase; i.e., in the upward phase of the bubble, expensive properties tend to increase in

- These assessment based methods cannot decompose a property price index into structure and land components.<sup>33</sup>

My overall evaluation of these assessment based methods is that they are quite satisfactory (and superior to repeat sales methods) if:

- The assessed values are used for taxation purposes;<sup>34</sup>
- The index is adjusted using other information for depreciation and renovations bias and
- Only a single index is required and a decomposition of the index into structure and land components is not required.

We turn now to another class of methods for constructing property price indexes.

### 4.3 Stratification Methods

Possibly the simplest approach to the construction of a real estate price index is to *stratify* or decompose the market into separate types of property, calculate the mean (or more commonly, the median) price for all properties transacted in that cell for the current period and the base period and then use the ratio of the means as a real estate price index.

The problem with this method can be explained as follows: if there are too many cells in the stratification, then there may not be a sufficient number of transactions in any given period in order to form an accurate cell average price but if there are too few cells in the stratification, then the resulting cell averages will suffer from *unit value bias*; i.e., the mix of properties sold in each period within each cell may change dramatically from period to period, and thus the resulting stratified indexes do not hold quality constant.

The stratification method can work well; for example, see Rosmundur and Jonsdottir (2006; 3-5) where they note that they work with some 8,000-10,000 real estate transactions per year in Iceland, which is a sufficient number of observations to be able to produce 30 monthly subindexes.<sup>35</sup> Within each cell, geometric rather than arithmetic averaging of prices is used:

“The geometric mean replaces the arithmetic mean when averaging house prices within each stratum at the elementary level. This is in line with the calculation method used at the elementary level in the Icelandic CPI. The geometric mean is also used in hedonic calculations and the geometric mean is a typical matched

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price more rapidly than cheaper ones and then in the downward phase, the prices of more expensive properties tend to fall more rapidly. A single index will not be able to capture these differential rates of price change.

<sup>33</sup> We show later in section 5.1 that the hedonic method can deal with this problem.

<sup>34</sup> A bit of caution is called for here: sometimes official assessments are not very accurate for various reasons.

<sup>35</sup> However, the monthly index is produced as a moving average: “The calculation of price changes for real estate is a three month moving average, with a one month delay.” Rosmundur Gudnason and Guorun Jonsdottir (2006; 4). Gudnason and Jonsdottir (2006; 3) also note that each year about 8-10 percent of all the housing in the country is bought and sold.

model estimator (Diewert (2003b) (2003c), de Haan (2003)). Rosmundur Gudnason and Guorun Jonsdottir (2006; 5).

Even though geometric averaging is difficult to explain to some users, it has much to recommend it since it is more likely that random “errors” in a particular stratum of real estate are multiplicative in nature rather than being additive; see also Chapters 16 and 20 of ILO (2004).

The Australian Bureau of Statistics (ABS) is also experimenting with stratification techniques in order to produce constant quality housing price indexes:

“The approach uses location (suburb) to define strata that group together (or ‘cluster’) houses that are ‘similar’ in terms of their price determining characteristics. Ideally, each suburb would form its own cluster as this would maximise the homogeneity of the cluster. However, there are insufficient numbers of observations from quarter to quarter to support this methodology. The ABS has grouped similar suburbs to form clusters with sufficient ongoing observations to determine a reliable median price. ABS research showed HPI (Housing Price Index) strata (or clusters of suburbs) were most effectively determined using an indicator of socio-economic characteristics: the median price, the percentage of three bedroom houses and the geographical location of the suburbs.” Merry Branson (2006; 5).

The ABS clustering procedures are very interesting and novel but one must be a bit cautious in interpreting the resulting price changes since any individual suburb might contain a mixture of properties and thus the resulting indexes may be subject to a certain amount of unit value bias.<sup>36</sup>

As usual, we close this section with a discussion of the advantages and disadvantages of the stratification approach to the construction of real estate price indexes.

It is useful to discuss the merits of the above appraisal methods compared to other methods for constructing real estate price indexes.

The *main advantages* of the stratification method are:

- The method is conceptually acceptable but it depends crucially on the choice of stratification variables.
- The method is reproducible, conditional on an agreed list of stratification variables.
- Housing price indexes can be constructed for different types and locations of housing.
- The method is relatively easy to explain to users.

The *main disadvantages* of the stratification method are:

- The method cannot deal adequately with depreciation of the dwelling units or structures.

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<sup>36</sup> However, Prasad and Richards (2006) show that the stratification method applied to Australian house price data gave virtually the same results as a hedonic model that had locational explanatory variables.

- The method cannot deal adequately with units that have undergone major repairs or renovations.
- The method requires some information on housing characteristics so that sales transactions can be allocated to the correct cell in the classification scheme.<sup>37</sup>
- If the classification scheme is very coarse, then there may be some unit value bias in the indexes.
- If the classification scheme is very fine, the detailed cell indexes may be subject to a considerable amount of sampling variability due to small sample sizes.
- The method cannot decompose a property price index into structure and land components.

My overall evaluation of the stratification method is that it can be quite satisfactory (and superior to the repeat sales and assessment methods<sup>38</sup>) if:

- An appropriate level of detail is chosen for the number of cells;
- The index is adjusted using other information for depreciation and renovations bias and
- A decomposition of the index into structure and land components is not required.

It is well known that stratification methods can be regarded as special cases of general hedonic regressions<sup>39</sup> and so we now turn to this more general technique.

#### 4.4 Hedonic Methods

Very detailed expositions of hedonic regression techniques applied to the property market can be found in some of the papers presented at this workshop; see in particular, Gouriéroux and Laferrère (2006) and Li, Prud'homme and Yu (2006). Although there are several variants of the technique, the basic model regresses the logarithm of the sale price of the property on the price determining characteristics of the property and a time dummy variable is added for each period in the regression (except the base period). Once the estimation has been completed, these time dummy coefficients can be exponentiated and turned into an index.<sup>40</sup>

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<sup>37</sup> If no information on housing characteristics is used, then the method is subject to tremendous unit value bias.

<sup>38</sup> The standard assessment method leads to only a single price index whereas the stratification method leads to a family of subindexes. However, if stratification variables are available, the assessment method can also produce a family of indexes.

<sup>39</sup> See Diewert (2003b) who showed that stratification techniques or the use of dummy variables can be viewed as a nonparametric regression technique. In the statistics literature, these partitioning or stratification techniques are known as analysis of variance models; see Scheffé (1959).

<sup>40</sup> An alternative approach to the hedonic method is to estimate separate hedonic regressions for both of the periods compared; i.e., for the base and current period. Predicted prices can then be generated in each period using the estimated hedonic regressions based on a constant characteristics set, say the characteristics of the base period. A ratio of the geometric means of the estimated prices in each period would yield a pure price comparison based on a constant base period set of characteristics. A hedonic index based on a constant current period characteristic could also be compiled, as could such indexes based on a symmetric use of base and current period information. Heravi and Silver (2007) outline alternative formulations and Silver and Heravi (2007) provide a formal analysis of the difference between this

Since the method assumes that information on the characteristics of the properties sold is available, the data can be stratified and a separate regression can be run for each important class of property. Thus the hedonic regression method can be used to produce a family of indexes.<sup>41</sup>

The issues associated with running weighted hedonic regressions are rather subtle and the recent literature on this topic will not be reviewed here.<sup>42</sup>

The usual hedonic regression model is not able to separate out the land and structures components of the property class under consideration but in section 5.1 below, we will explain how the usual method can be modified to give us this decomposition.

As usual, it is useful to discuss the merits of the hedonic regression method compared to other methods for constructing real estate price indexes.

The *main advantages* of the hedonic regression method are:

- Property price indexes can be constructed for different types and locations of the property class under consideration.
- The method is probably the most efficient method for making use of the available data.
- The method can be modified to give a decomposition of property prices into land and structures components (see section 5.1 below); none of the other methods described so far can do this.
- If the list of property characteristics is sufficiently detailed, so that, for example, it can be determined whether major maintenance projects have been undertaken and when they were done (such as a new roof), then it may be possible to deal adequately with the depreciation and renovations problems.

The *main disadvantages* of the hedonic method are:

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approach and that of the time dummy method. The French method also does not use the time dummy method but is too complex to explain here.

<sup>41</sup> This property of the hedonic regression method also applies to the stratification method. The main difference between the two methods is that continuous variables can appear in hedonic regressions (like the area of the structure and the area of the lot size) whereas the stratification method can only work with discrete ranges for the independent variables in the regression.

<sup>42</sup> Basically, this recent literature makes connections between weighted hedonic regressions and traditional index number formula that use weights; see Diewert (2003c) (2004) (2005a) (2005b), de Haan (2003) (2004), Silver (2003) and Silver and Heravi (2005). It is worth noting that a perceived advantage of the stratification method is that *median* price changes can be measured as opposed to *arithmetic mean* ones, that are implicit in a say ordinary least squares estimator. However, regression estimates can also be derived from robust estimators from which the parameter estimates for the price change will be similar to a median.

- The method is data intensive (i.e., it requires information on property characteristics) and thus it is relatively expensive to implement.
- The method is not entirely reproducible; i.e., different statisticians will enter different property characteristics into the regression,<sup>43</sup> assume different functional forms for the regression equation, make different stochastic specifications and perhaps choose different transformations of the dependent variable<sup>44</sup>, all of which leads to perhaps different estimates of the amount of overall price change.
- The method is not easy to explain to users.

My overall evaluation of the hedonic regression method is that it is probably the best method that could be used in order to construct constant quality price indexes for various types of property.<sup>45</sup> Note that the paper by Gouriéroux and Laferrère (2006) demonstrates that it is possible to construct an official nationwide credible hedonic regression model for real estate properties.

In the following 2 sections, we will discuss some additional technical issues that emerged from the workshop. In particular, in section 5.1 below, we will show how the hedonic regression technique can be modified to provide a structures and land price decomposition of property price movements.

## 5. Other Technical Issues

### 5.1 The Decomposition of Real Estate Values into Land and Structure Components<sup>46</sup>

If we momentarily think like a property developer who is planning to build 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  $A$  square meters, times the building cost per square meter,  $\alpha$  say, plus the cost of the land, which will be equal to the cost per square meter,  $\beta$  say, times the area of the land site,  $B$ . Now think of a sample of properties of the same general type, which have prices  $p_n^0$  in period 0 and structure areas  $A_n^0$  and land areas  $B_n^0$  for  $n = 1, \dots, N(0)$ , and these prices are equal to costs of the above type times error terms  $\eta_n^0$  which we assume have mean 1. This leads to the following hedonic regression model for period 0 where  $\alpha$  and  $\beta$  are the parameters to be estimated in the regression:<sup>47</sup>

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<sup>43</sup> Note that the same criticism can be applied to stratification methods; i.e., different analysts will come up with different stratifications.

<sup>44</sup> For example, the dependent variable could be the sales price of the property or its logarithm or the sales price divided by the area of the structure and so on.

<sup>45</sup> This evaluation agrees with that of Hoffmann and Lorenz: "As far as quality adjustment is concerned, the future will certainly belong to hedonic methods." Johannes Hoffman and Andreas Lorenz (2006; 15).

<sup>46</sup> Discussions with Anne Laferrère helped improve the initial oral presentation of the model presented in this section.

<sup>47</sup> Multiplicative errors with constant variances are more plausible than additive errors with constant variances; i.e., it is more likely that expensive properties have relatively large absolute errors compared to

$$(21) p_n^0 = [\alpha A_n^0 + \beta B_n^0] \eta_n^0 ; \quad n = 1, \dots, N(0).$$

Taking logarithms of both sides of (21) leads to the following traditional additive errors regression model:<sup>48</sup>

$$(22) \ln p_n^0 = \ln[\alpha A_n^0 + \beta B_n^0] + \varepsilon_n^0 ; \quad n = 1, \dots, N(0)$$

where the new error terms are defined as  $\varepsilon_n^0 \equiv \ln \eta_n^0$  for  $n = 1, \dots, N(0)$  and are assumed to have 0 means and constant variances.

Now consider the situation in a subsequent period  $t$ . The price per square meter of this type of structure will have changed from  $\alpha$  to  $\alpha\gamma^t$  and the land cost per square meter will have changed from  $\beta$  to  $\beta\delta^t$  where we interpret  $\gamma^t$  as the *period 0 to t price index for the type of structure* and  $\delta^t$  as the *period 0 to t price index for the land that is associated with this type of structure*. The period  $t$  counterparts to (21) and (22) are:

$$(23) p_n^t = [\alpha\gamma^t A_n^t + \beta\delta^t B_n^t] \eta_n^t ; \quad n = 1, \dots, N(t);$$

$$(24) \ln p_n^t = \ln[\alpha\gamma^t A_n^t + \beta\delta^t B_n^t] + \varepsilon_n^t ; \quad n = 1, \dots, N(t)$$

where  $\varepsilon_n^t \equiv \ln \eta_n^t$  for  $n = 1, \dots, N(t)$ , the period  $t$  property prices are  $p_n^t$  and the corresponding structure and land areas are  $A_n^t$  and  $B_n^t$  for  $n = 1, \dots, N(t)$ .

Equations (22) and (24) can be run as a system of nonlinear hedonic regressions and estimates can be obtained for the 4 parameters,  $\alpha$ ,  $\beta$ ,  $\gamma^t$  and  $\delta^t$ . The main parameters of interest are of course,  $\gamma^t$  and  $\delta^t$ , which can be interpreted as price indexes for the price of a square meter of this type of structure and for the price per meter squared of the underlying land respectively.

The above very basic nonlinear hedonic regression framework can be generalized to encompass the traditional array of characteristics that are used in real estate hedonic regressions. Thus suppose that we can associate with each property  $n$  that is transacted in each period  $t$  a list of  $K$  characteristics  $X_{n1}^t, X_{n2}^t, \dots, X_{nK}^t$  that are price determining characteristics for the structure and a similar list of  $M$  characteristics  $Y_{n1}^t, Y_{n2}^t, \dots, Y_{nM}^t$  that are price determining characteristics for the type of land that sits underneath the structure. The equations which generalize (22) and (24) to the present setup are the following ones:

$$(25) \ln p_n^0 = \ln \{ [\alpha_0 + \sum_{k=1}^K X_{nk}^0 \alpha_k] A_n^0 + [\beta_0 + \sum_{m=1}^M Y_{nm}^0 \beta_m] B_n^0 \} + \varepsilon_n^0 ; \quad n = 1, \dots, N(0);$$

$$(26) \ln p_n^t = \ln \{ \gamma^t [\alpha_0 + \sum_{k=1}^K X_{nk}^t \alpha_k] A_n^t + \delta^t [\beta_0 + \sum_{m=1}^M Y_{nm}^t \beta_m] B_n^t \} + \varepsilon_n^t ; \quad n = 1, \dots, N(t);$$

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very inexpensive properties. The multiplicative specification for the errors will be consistent with this phenomenon.

<sup>48</sup> However, note that this model is not linear in the unknown parameters to be estimated.

where the parameters to be estimated are now the  $K+1$  quality of structure parameters,  $\alpha_0, \alpha_1, \dots, \alpha_K$ , the  $M+1$  quality of land parameters,  $\beta_0, \beta_1, \dots, \beta_M$ , the period  $t$  price index for structures parameter  $\gamma^t$  and the period  $t$  price index for the land underlying the structures parameter  $\delta^t$ . Note that  $[\alpha_0 + \sum_{k=1}^K X_{nk} \alpha_k]$  in (25) and (26) replaces the single structures quality parameter  $\alpha$  in (22) and (24) and  $[\beta_0 + \sum_{m=1}^M Y_{nm} \beta_m]$  in (25) and (26) replaces the single land quality parameter  $\beta$  in (22) and (24).

In order to illustrate how  $X$  and  $Y$  variables can be formed, we consider the list of exogenous variables in the hedonic housing regression model reported by Li, Prud'homme and Yu (2006; 23). The following variables in their list of exogenous variables can be regarded as variables that affect structure quality; i.e., they are  $X$  type variables: number of reported bedrooms, number of reported bathrooms, number of garages, number of fireplaces, age of the unit, age squared of the unit, exterior finish is brick or not, dummy variable for new units, unit has hardwood floors or not, heating fuel is natural gas or not, unit has a patio or not, unit has a central built in vacuum cleaning system or not, unit has an indoor or outdoor swimming pool or not, unit has a hot tub unit or not, unit has a sauna or not, and unit has air conditioning or not. The following variables can be regarded as variables that affect the quality of the land; i.e., they are  $Y$  type location variables: unit is at the intersection of two streets or not (corner lot or not), unit is at a cul-de-sac or not, shopping center is nearby or not, and various suburb location dummy variables.<sup>49</sup>

The nonlinear hedonic regression model defined by (25) and (26) is very flexible and can accomplish what none of the other real estate price index construction methods were able to accomplish: namely a decomposition of a property price index into structures and land components. However, this model has a cost compared to the usual hedonic regression model discussed in section 4.4: the previous class of models was linear in the unknown parameters to be estimated whereas the model defined by (25) and (26) is highly nonlinear. It remains to be seen whether such a highly nonlinear model can be estimated successfully for a large data set.<sup>50</sup>

## 5.2 Weighting and Formula Issues

Most of the papers presented at the workshop did not delve too deeply into weighting and formula issues, with some exceptions, such as the paper by Rosmundur and Jonsdottir

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<sup>49</sup> Of course, in practice, some of the land or location variables could act as proxies for unobserved structure quality variables. There are also some interesting conceptual problems associated with the treatment of rental apartments and owner occupied apartments or condominiums. Obviously, separate hedonic regressions would be appropriate for apartments since their structural characteristics are quite different from detached housing. For rental apartments, the sale price of the apartment can be the dependent variable and there will be associated amounts of structure area and land area. For a condo sale, the price of the single unit is the dependent variable while the dependent variables in the bare bones model would be structure area of the apartment plus the apartment's share of commonly owned facilities plus the apartment's share of the lot area. In the end, we want to be able to impute the value of the property into land and structure components and so the hedonic regression should be set up so as to accomplish this task.

<sup>50</sup> Of course, large data sets can be transformed into smaller data sets if we run separate hedonic regressions for various property strata!

(2006). However, for all of the methods except the hedonic regression methods, the advice on formulae and weighting given in the ILO *CPI Manual* (2004) seems relevant and the reader is advised to consult the appropriate chapters. For hedonic methods, we noted the recent literature on weighting and the reader is advised to consult this literature.

Perhaps it is worth repeating some of Diewert's observations on weighting problems that can arise if we use the acquisitions approach to housing:

“Some differences between the acquisitions approach and the other approaches are:

- If rental or leasing markets for the durable exist and the durable has a long useful life, then the expenditure weights implied by the rental equivalence or user cost approaches will typically be much larger than the corresponding expenditure weights implied by the acquisitions approach.
- If the base year corresponds to a boom year (or a slump year) for the durable, then the base period expenditure weights may be too large or too small. Put another way, the aggregate expenditures that correspond to the acquisitions approach are likely to be more volatile than the expenditures for the aggregate that are implied by the rental equivalence or user cost approaches.
- In making comparisons of consumption across countries where the proportion of owning versus renting or leasing the durable varies greatly,<sup>51</sup> the use of the acquisitions approach may lead to misleading cross country comparisons. The reason for this is that opportunity costs of capital are excluded in the net acquisitions approach whereas they are explicitly or implicitly included in the other two approaches.” W. Erwin Diewert (2003a, 7-8).

### **5.3 The Frequency Issue and the Consistency of Quarterly with Annual Estimates**

For inflation monitoring purposes, central banks would like to have property price indexes produced on a monthly or quarterly basis. Given the fact that the number of observations for a monthly index will only be approximately one third the number for a quarterly index, statistical agencies will have to carefully evaluate the timeliness-quality tradeoff.

Another question arises in this context: how can monthly or quarterly estimates of real estate inflation be made consistent with annual estimates?

The answer to this question is not simple because of two problems:

- The existence of seasonal factors; i.e., during some seasons (e.g., winter) real estate sales tend to be more sparse and there may be seasonal fluctuations in prices.<sup>52</sup>
- For high inflation countries, the price levels in the last month or quarter can be very much higher than those prevailing in the first quarter, leading to various conceptual difficulties.

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<sup>51</sup> From Hoffmann and Kurz (2002; 3-4), about 60% of German households live in rented dwellings whereas only about 11% of Spaniards rent their dwellings in 1999 (private communication).

<sup>52</sup> Hoffmann and Kurz-Kim (2006) provide some recent evidence of seasonality in German prices.

If there is high inflation within the year, then when annual unit value prices are computed (to correspond to total annual production of the commodities under consideration), “too much” weight will be given to the prices of the fourth quarter compared to the prices in the first quarter.<sup>53</sup> There are possible solutions to this problem but they are rather complex and there is no consensus on what the appropriate solution should be.

For possible solutions to the above problems, the reader is referred to Hill (1996), Diewert (1998) (1999), Bloem, Dippelsman and Maehle (2001) and Armknecht and Diewert (2004).

#### **5.4 Revision Policies**

Many of the papers presented at this conference noted the difficulties in assembling timely data on property sales. Since many of these difficulties seem rather intractable, it seems sensible to *not* apply the usual Consumer Price Index methodology to Real Estate Price indexes<sup>54</sup>; i.e., revisions should be allowed for Real Estate price indexes. This will create some problems for CPI indexes that apply a user cost approach to Owner Occupied Housing, since the user cost will depend on accurate property price indexes, which will generally only be available with a lag. The same problem will occur if the Harmonized Index of Consumer Prices decides to implement an acquisitions approach to Owner Occupied Housing.<sup>55</sup> One solution might be that users will be given a flagship CPI or HICP that makes use of preliminary or forecasted data and finally adjusted indexes will only be made available as “analytic” series. This issue requires more discussion.

#### **5.5 The Renovations versus Depreciation Problem**

Renovations increase the quality of a property and depreciation decreases the quality of a property and typically, both phenomena are not directly observed, making the construction of constant quality real estate price indexes extremely difficult if not impossible. How can we deal with this issue?

Perhaps the best way to deal with this problem is for statistical agencies to have a fairly extensive *renovations and repair survey* for both households and businesses. If renovations expenditures can be tracked over time back to a base period for individual properties that have sold in the current period and a base period estimate for the value of the property is available, then this information can be used in a hedonic regression model along the lines indicated in section 5.1 and scientific estimates of depreciation can be obtained. On the business side of property markets, the situation is not as bad, since businesses normally keep track of major renovations in their asset registers and this information could be accessed in investment surveys that also ask questions about asset

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<sup>53</sup> See Hill (1996) and Diewert (1998) for a discussion of these problems.

<sup>54</sup> The usual CPI methodology is to never revise the index.

<sup>55</sup> For an update on how thinking is progressing on the treatment of Owner Occupied Housing in the HICP, see Makaronidis and Hayes (2006).

sales and retirements. Canada,<sup>56</sup> the Netherlands<sup>57</sup> and New Zealand ask such questions on retirements in their investment surveys and Japan is about to follow suit.<sup>58</sup> Diewert and Wykoff (2006) indicate how this type of survey can be used to obtain estimates for depreciation rates.

There are a number of technical details that remain to be explored in this area. It is an important area of research that needs further development.

The final technical problem that arose out of the workshop is sufficiently important that it deserves a separate section. The question which the paper by Verbrugge (2006) raised is this: are user costs so volatile and unpredictable that they are pretty much useless in a statistical agency real estate price index?

## 6. User Costs versus Rental Equivalence

Perhaps the most interesting and provocative paper presented at the Workshop was the paper by Verbrugge. He summarized his paper as follows:

“I construct several estimates of *ex ante* user costs for US homeowners, and compare these to rents. There are three novel findings. First, a significant volatility divergence remains even for *ex ante* user cost measures which have been smoothed to mimic the implicit smoothing in the rent data. Indeed, the volatility of smoothed quarterly aggregate *ex ante* user cost growth is about 10 times greater than that of aggregate rent growth. This large volatility probably rules out the use of *ex ante* user costs as a measure of the costs of homeownership.

The second novel finding is perhaps more surprising: not only do rents and user costs diverge in the short run, but the gaps persist over extended periods of time. ...

The divergence between rents and user costs highlights a puzzle, explored in greater depth below: rents do not appear to respond very strongly to their theoretical determinants. ...

Despite this divergence, the third novel finding is that there were evidently no unexploited profit opportunities. While the detached unit rental market is surprisingly thick, and detached housing is readily moved between owner and renter markets ..., the large costs associated with real estate transactions would have prevented risk neutral investors from earning expected profits by using the transaction sequence *buy, earn rent on property, sell*, and would have prevented risk neutral homeowners from earning expected profits by using the transaction sequence *sell, rent for one year, repurchase*.” Randal Verbrugge (2006; 3).

How did Verbrugge arrive at the above conclusions? He started off with the following expression for the user cost  $u_i^t$  of home  $i$ :<sup>59</sup>

$$(27) u_i^t = P_i^t (i^t + \delta - E\pi_i^t)$$

where

<sup>56</sup> For a description and further references to the Canadian program on estimating depreciation rates, see Baldwin, Gellatly, Tanguay and Patry (2005).

<sup>57</sup> Actually, since 1991, the Dutch have a separate (mail) survey for enterprises with more than 100 employees to collect information on discards and retirements: The Survey on Discards; see Bergen, Haan, Heij and Horsten (2005; 8) for a description of the Dutch methods.

<sup>58</sup> The Economic and Social Research Institute (ESRI), Cabinet Office of Japan, with the help of Koji Nomura is preparing a new survey to be implemented as of the end of 2006.

<sup>59</sup> See formula (1) in Verbrugge (2006; 11). We have not followed his notation exactly.

- $P_i^t$  is the price of home  $i$  in period  $t$ ;
- $i^t$  is a nominal interest rate;<sup>60</sup>
- $\delta$  is the sum of annual depreciation, maintenance and repair, insurance, property taxes and potentially a risk premium;<sup>61</sup> and
- $E\pi_i^t$  represents the expected annual constant quality home appreciation rate for home  $i$  at period  $t$ .<sup>62</sup>

Thus the resulting user cost can be viewed as an opportunity cost measure for the annual cost of owning a home starting at the beginning of the quarter indexed by time  $t$ . Presumably, landlords, when they set an annual rent for a dwelling unit, would use a formula similar to (27) in order to determine the rent for a tenant.<sup>63</sup> So far, there is nothing particularly controversial about Verbrugge's analysis. What is controversial was Verbrugge's determination of the expected house price appreciation term,  $E\pi_i^t$ :

“Rather than using a crude proxy, I will construct a *forecast* for  $E\pi_i^t$ , as described below. This choice is crucial, for four reasons. First, expected home price appreciation is extremely volatile; setting this term to a constant is strongly at odds with the data, and its level of volatility will be central to this study. Second, this term varies considerably across cities, and its temporal dynamics might well vary across cities as well. Third, the properties of  $(i^t - E\pi_i^t)$  are central to user cost dynamics, yet these properties are unknown (or at least, not documented); again, setting  $E\pi_i^t$  to a constant (or even to a long moving average) would be inappropriate for this study, since this choice obviously suppresses the correlation between  $i^t$  and  $E\pi_i^t$ . Finally, the recent surge in  $E\pi_i^t$  is well above its 15 year average, and implies that the user cost/rent ratio has fallen dramatically. A *single* year appreciation rate is used since we are considering the *one year* user cost, in order to remain comparable to the typical rental contract.” Randal Verbrugge (2006; 12).

Verbrugge (2006; 13) went on to use various econometric forecasting techniques to forecast expected price appreciation for his one year horizon, he inserted these forecasts into the user cost formula (27) above and obtained tremendously volatile ex ante user costs and the rest of his conclusions followed.

However, it is unlikely that landlords use econometric forecasts of housing price appreciation one year away and adjust rents for their tenants every year based on these forecasts. Tenants do not like tremendous volatility in their rents and any landlord that attempted to set such volatile rents would soon have very high vacancy rates on his or her properties.<sup>64</sup> It is however possible that landlords may have some idea of the long run

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<sup>60</sup> Verbrugge (2006; 11) used either the current 30 year mortgage rate or the average one year Treasury bill rate and noted that the choice of interest rate turned out to be inconsequential for his analysis.

<sup>61</sup> Verbrugge (2006; 13) assumed that  $\delta$  was approximately equal to 7 %. Note that the higher the volatility in house prices is, the higher the risk premium would be for a risk averse consumer.

<sup>62</sup>  $\pi_i^t$  is the actual 4 quarter (constant quality) home price appreciation between the beginning of period  $t$  and one year from this period.

<sup>63</sup> Diewert (2003a) noted that there would be a few differences between a user cost formula for an owner occupier as compared to a landlord but these differences are not important for Verbrugge's analysis.

<sup>64</sup> Hoffmann and Kurz-Kim find that German rents are changed only once every 4 years on average: “In Germany, as in other euro area countries, prices of most products change infrequently, but not incrementally. Pricing seems to be neither continuous nor marginal. In our sample, prices last on average more than two years—if price changes within a month are not considered—but then change by nearly 10

average rate of property inflation for the type of property that they manage and this long run average annual rate of price appreciation could be inserted into the user cost formula (27).<sup>65</sup>

Looking at the opportunity costs of owning a house from the viewpoint of an owner occupier, the relevant time horizon to consider for working out an annualized average rate of expected price appreciation is the expected time that the owner expects to use the dwelling before reselling it. This time horizon is typically some number between 6 and 12 years so again, it does not seem appropriate to stick annual forecasts of expected price inflation into the user cost formula. Once we use annualized forecasts of expected price inflation over longer time horizons, the volatility in the ex ante user cost formula will vanish or at least be much diminished.

Another method for reducing the volatility in the user cost formula is to replace the nominal interest rate less expected price appreciation term  $(i^t - E\pi_i^t)$  by a constant or a slowly changing long run average *real interest rate*,  $r^t$  say. This is what is done in Iceland<sup>66</sup> and the resulting user cost seems to be acceptable to the population (and it is not overly volatile).

Verbrugge had an interesting section in his paper that helps to explain why user costs and market rentals can diverge so much over the short run. The answer is high transactions costs involved in selling or purchasing real estate properties prevent arbitrage opportunities:<sup>67</sup>

“The first question is thus answered: there is no evidence of unexploited profits for prospective landlords. How about the second: was there ever a period of time in any city during which a ‘median’ homeowner should have sold his house, rented for a year, and repurchased his house a year later? ... In this case, it appears that for Los Angeles, there was a single year, 1994, during which a homeowner should have sold her house, rented for a year, and repurchased her house. For every other time period, and for the entire period for the other four cities, a homeowner was always better off remaining in his house.” Randal Verbrugge (2006; 36).

Since high real estate transactions costs prevent the exploitation of arbitrage opportunities between owning and renting a property, user costs can differ considerably over the corresponding rental equivalence measures over the lifetime of a property cycle.

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% . The longest price durations are found for housing rents, which, on average, are for more than four years.” Johannes Hoffmann and Jeong-Ryeol Kurz-Kim (2006; 5).

<sup>65</sup> The paper by Girouard, Kennedy, van den Noord and André nicely documents the length of housing booms and busts: “To qualify as a major cycle, the appreciation had to feature a cumulative real price increase equalling or exceeding 15%. This criterion identified 37 such episodes, corresponding to about two large upswings on average per 35 years for English speaking and Nordic countries and to 1½ for the continental European countries.” Nathalie Girouard, Mike Kennedy, Paul van den Noord and Christophe André (2006; 6). Thus one could justify taking 10 to 20 year (annualized) average rates of property price inflation in the user cost formula rather than one year rates.

<sup>66</sup> See Rosmundur (2004) and Rosmundur and Jonsdottir (2006; 11).

<sup>67</sup> Verbrugge (2006; 35) assumed that the transactions costs in the U.S. were approximately 8 to 10 percent of the sales price.

We conclude this section with the following (controversial) observation: perhaps the “correct” opportunity cost of housing for an owner occupier is not his or her internal user cost but the *maximum* of the internal user cost and what the property could rent for on the rental market. After all, the concept of opportunity cost is supposed to represent the *maximum sacrifice* that one makes in order to consume or use some object and so the above point would seem to follow. If this point of view is accepted, then at certain points in the property cycle, user costs would replace market rents as the “correct” pricing concept for owner occupied housing, which would dramatically affect Consumer Price Indexes and the conduct of monetary policy.<sup>68</sup>

## 7. The Way Forward

The following points emerged as a result of the Workshop:

- The needs of users cannot be met by a single housing (or more generally, by a single real estate) price index.
- There is a demand for official real estate price indexes that are at least roughly comparable across countries.
- Statistical agencies should not produce multiple indexes that measure the same thing.
- The System of National Accounts should be the starting point for providing a systematic framework for a family of real estate price indexes.<sup>69</sup>
- It may well be that cooperation between the private sector and statistical agencies is the way forward in this area; the papers by Gouriéroux and Laferrère (2006) and Li Prud’homme and Yu (2006) show that this type of cooperation is possible.
- It would be very useful for the various international agencies to cooperate in producing an international Manual or Handbook of Methods on Real Estate Price Indexes so that national real estate price indexes can be harmonized across countries (or at least be more harmonized).
- It would be useful to produce a country inventory of practices in the real estate price index area.
- The OECD should take the lead in producing the Manual and the inventory of practices.
- There is a need for the Manual writers to talk to users about their needs in this area.
- The listing of properties on the internet may well facilitate the development of high quality property price indexes and may do the same for residential property price indexes as scanner data did for ordinary consumer price indexes.<sup>70</sup>

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<sup>68</sup> Woolford (2006) shows that different treatments of Owner Occupied Housing in the Australian context generate very different aggregate consumer price indexes.

<sup>69</sup> As was noted above in section 2, it is necessary to look beyond the present SNA to the next version which will probably have a more detailed treatment of durable goods in it so that consumer service flows can be better measured and so that productivity accounts can be constructed for the business sector. A natural family of real estate price indexes emerges from this expanded SNA.

<sup>70</sup> Johannes Hoffmann made this point.

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